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The last Space Shuttle commander
CHRISTOPHER J FERGUSON

All About Space

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20 SECRETS OF THE UNIVERSE REVEALED

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The mission to find valuable resources in giant space rocks

THE HUNT FOR EXOPLANETS
Meet the scientists searching for Earth-like worlds

+
SOAR MINI-SHUTTLE
THE MOON
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KNOW YOUR GALAXIES
Identifying massive galactic formations

PROXIMA CENTAURI
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Blast off to a universe of knowledge

"There are few things in life that are comparable to getting selected to go on a spaceflight"
44 Christopher J Ferguson, the last Shuttle commander

All About Space is one year old this issue. We admit, it's not quite as auspicious a landmark as the discovery of the first confirmed exoplanet, for example, which was found in orbit around the star Gamma Cephei by astronomers Campbell, Walker and Yang, 25 years ago this year. But we have made it to our first birthday before the Mars rover Curiosity has the chance to steal our thunder, with the first anniversary of its landing in August.

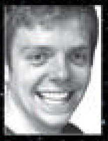
Our main feature this issue, Planet Hunters on page 32, takes a look at the technology and the new alien worlds being discovered just beyond Earth's back yard, but its main focus is on the people searching for these exoplanets. These are the scientists and astronomers who can take a stream of incomprehensible digits and wavy analogue lines from the battery of hi-tech instruments they have at their disposal, then paint a picture of distant super-Earths, rocky globes and molten hot Jupiters orbiting stars a tantalising breadth beyond the reach of our most sensitive gear. It takes a particular type of person with the knowledge, patience and imagination to stake out the stars in the search for planets beyond the Solar System: we're speaking to five of them.

With asteroid mining, the discovery of life on other worlds and missions to Mars having moved beyond the realms of complete science fiction and towards potential reality in the last year, we hope you find that it's as exciting a time to be reading a young space magazine as it is for us to make one. Enjoy!

Ben Biggs
Deputy Editor

Crew roster

Jonathan O'Callaghan



■ Jonny spent so much time interviewing, he nearly didn't have time to pen Planet Hunters. Nearly

Shanna Freeman

■ Proxima Centauri, our nearest star, was taken on by our intrepid regular, Shanna

Giles Sparrow

■ Giles got immersed in the 20 biggest mysteries of space, present & past, this issue

Nigel Watson

■ Nigel explains exactly what Edwin Hubble's galactic tuning fork is all about, on page 30

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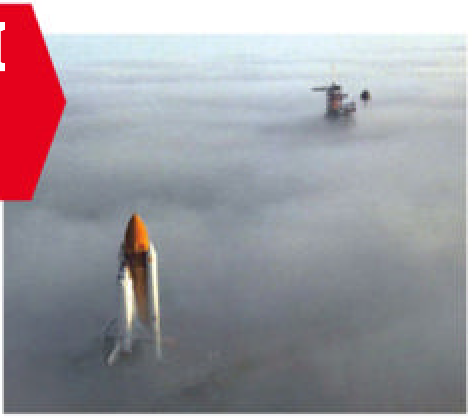

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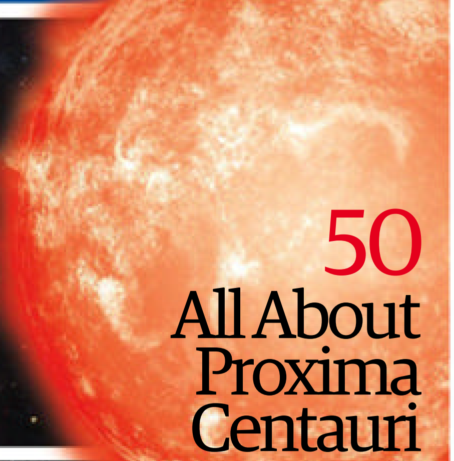

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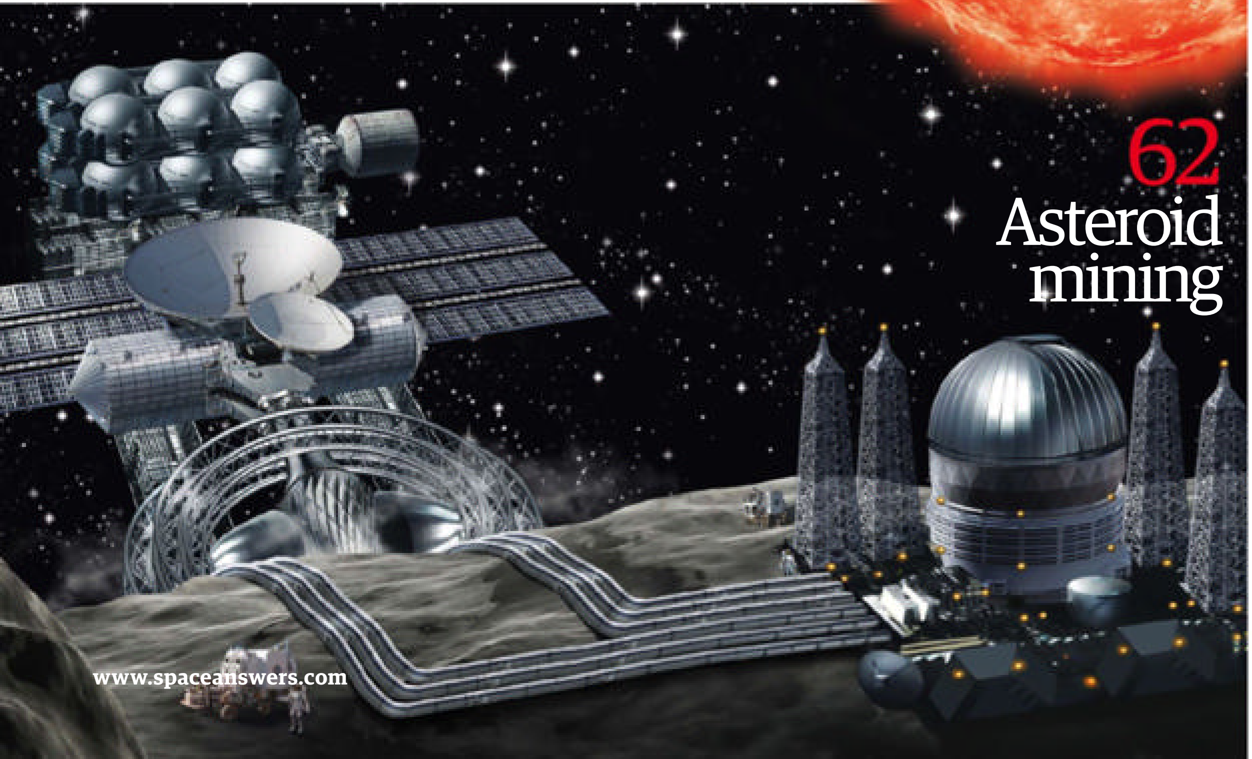

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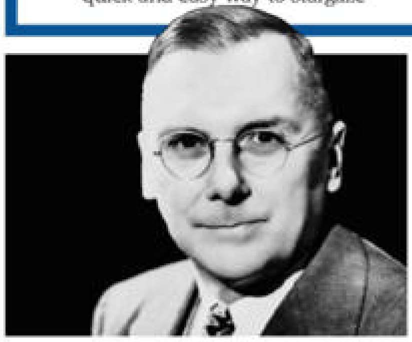

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Hugh L Dryden, the man who helped build NASA

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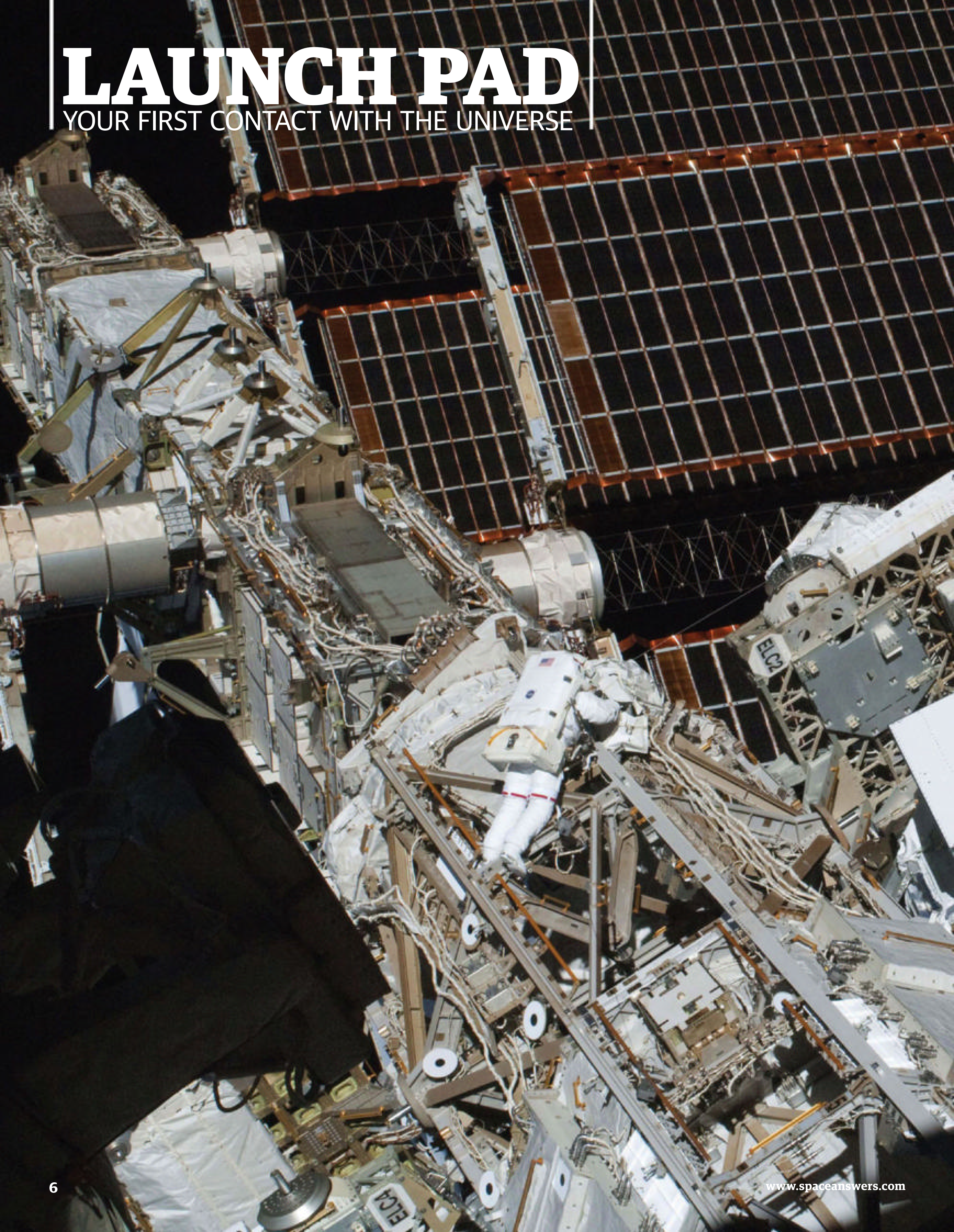
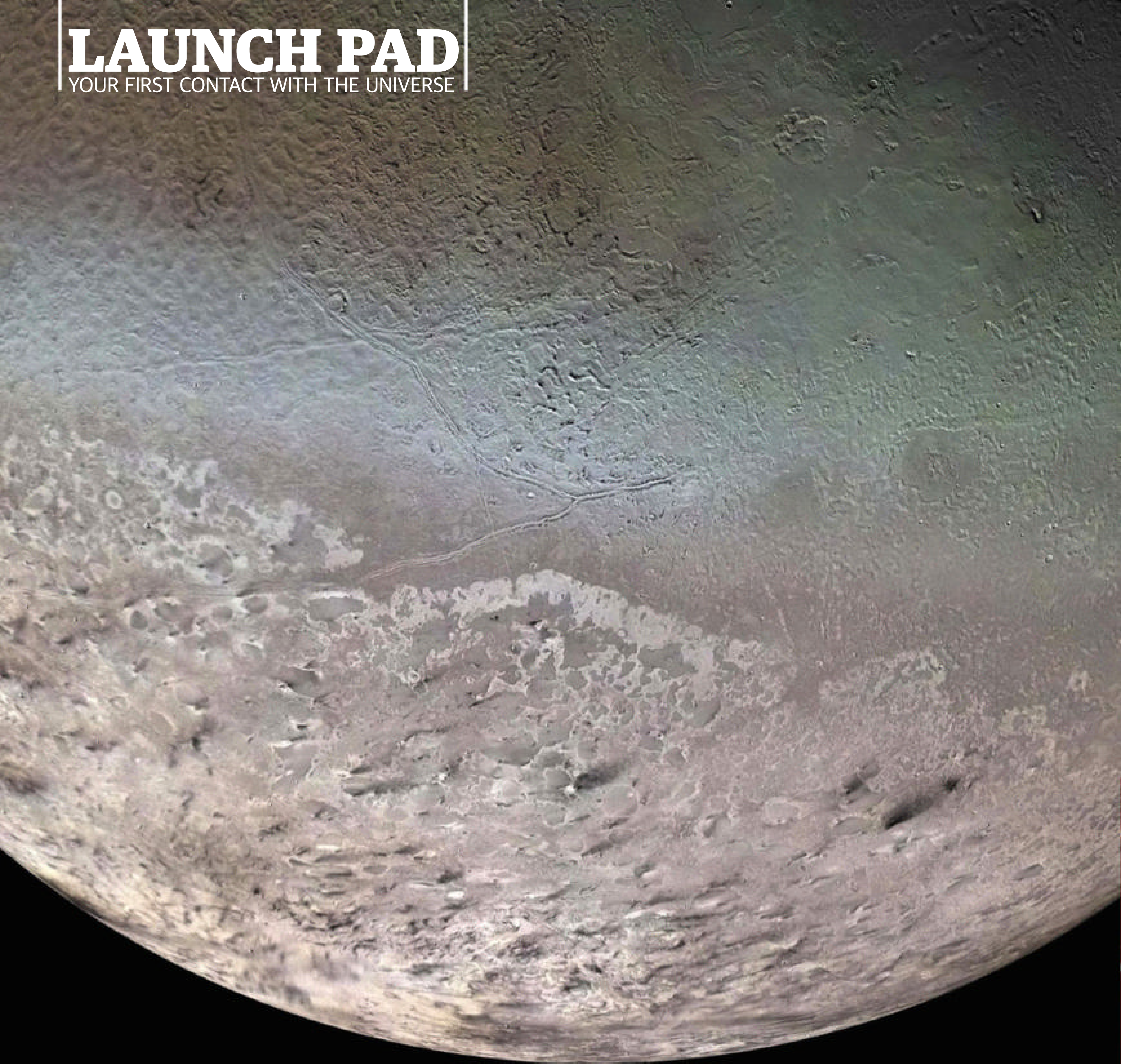


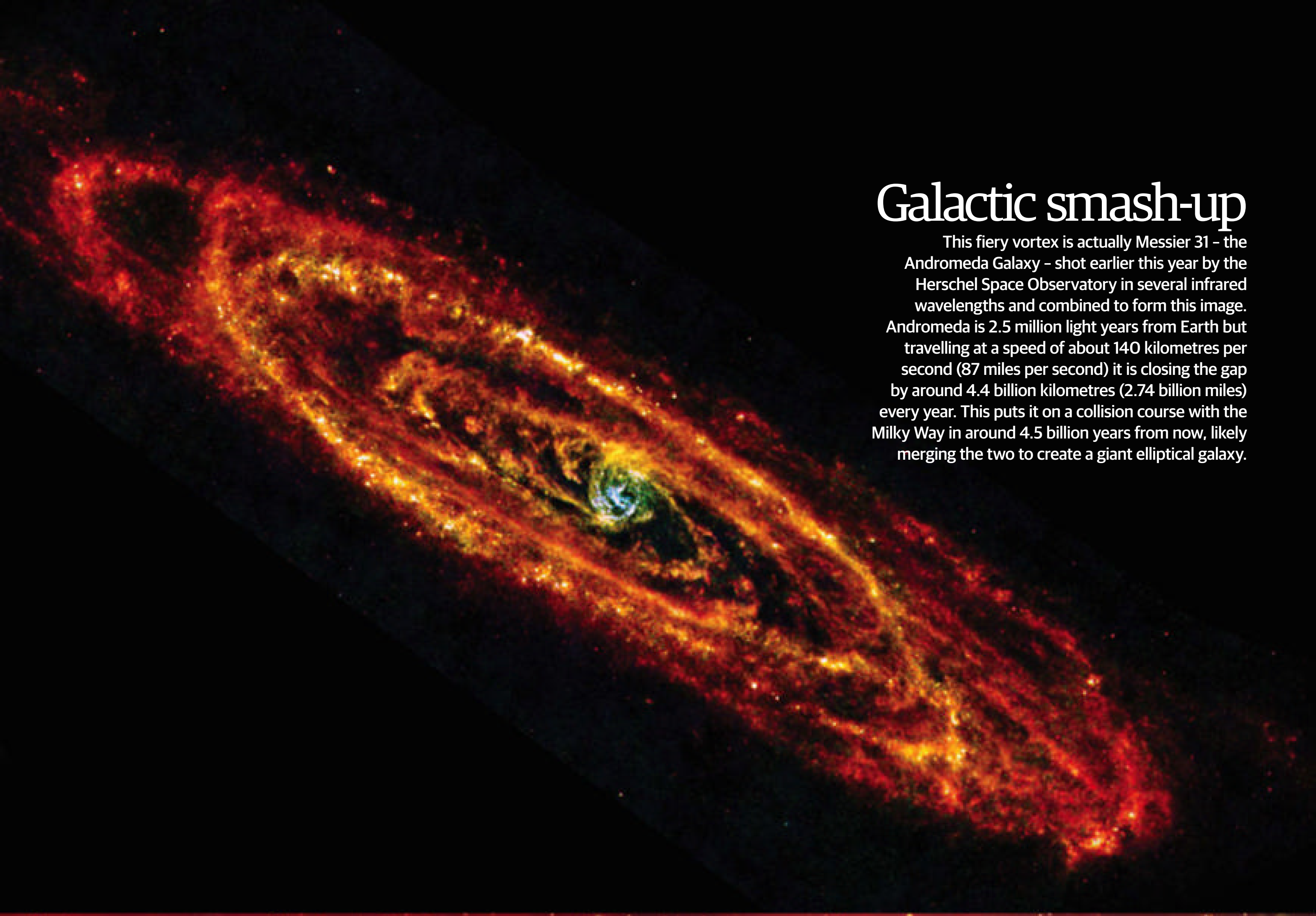
Dark matter hunter

This photo was taken shortly after the AMS-02 antimatter hunter (located just in front of the solar panel on the right-hand page) was installed on the International Space Station in 2011. Since its installation it has recorded over 30 billion cosmic ray events and observed more than 400,000 positrons that result from the destruction of dark matter particles.



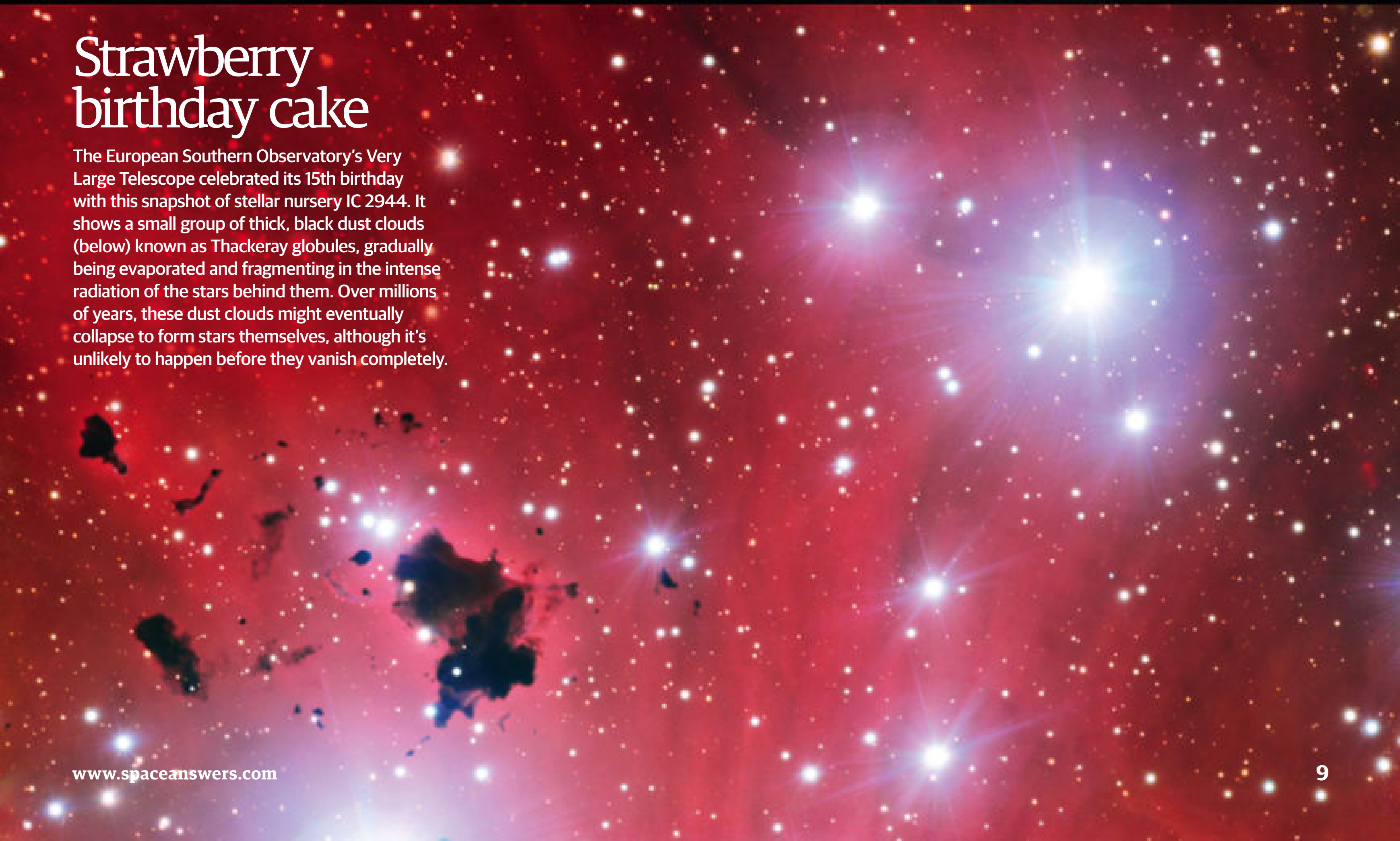
Outer-space melon

Triton took scientists and engineers by surprise when this photo was taken of it in 1989 by Voyager 2. The close-up of the Neptunian satellite was expected to show a cold and rocky surface. However, it also revealed a south polar ice cap made of methane ice turning pink in ultraviolet light, strange carbonaceous smoke-stacks and a greenish 'cantaloupe' area that still isn't understood. "When we got to Neptune the big surprise was Triton's terrain," said New Horizons co-investigator, Professor Fran Bagenal. "It was very bizarre – it still is bizarre, I don't think we really understand it."



Galactic smash-up

This fiery vortex is actually Messier 31 – the Andromeda Galaxy – shot earlier this year by the Herschel Space Observatory in several infrared wavelengths and combined to form this image. Andromeda is 2.5 million light years from Earth but travelling at a speed of about 140 kilometres per second (87 miles per second) it is closing the gap by around 4.4 billion kilometres (2.74 billion miles) every year. This puts it on a collision course with the Milky Way in around 4.5 billion years from now, likely merging the two to create a giant elliptical galaxy.



Strawberry birthday cake

The European Southern Observatory's Very Large Telescope celebrated its 15th birthday with this snapshot of stellar nursery IC 2944. It shows a small group of thick, black dust clouds (below) known as Thackeray globules, gradually being evaporated and fragmenting in the intense radiation of the stars behind them. Over millions of years, these dust clouds might eventually collapse to form stars themselves, although it's unlikely to happen before they vanish completely.

Coming through

This is the Space Shuttle Challenger as it moves through the fog on the back of the crawler transporter on 30 November 1982. The 800-metre (2,600-foot) crawl from the Vehicle Assembly Building to launch pad 39A to undergo both pad processing and mandatory Flight Readiness Firing (FRF) took six hours. Challenger launched the following year and went on to fly nine successful missions before the disastrous tenth mission in 1986, when it broke apart 73 seconds into launch, killing all seven astronauts on board.

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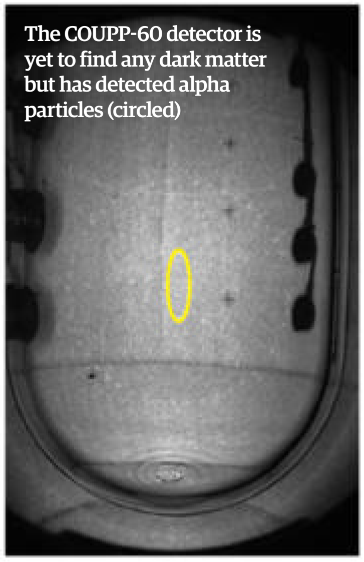
The installation of the COUPP-60 detector, overseen by Hugh Lippincott and fellow scientists

New dark matter detector placed deep underground

A tank of water and a fire extinguisher over 2.4 kilometres (1.5 miles) beneath the surface aims to find dark matter



The COUPP-60 detector is yet to find any dark matter but has detected alpha particles (circled)

COUPP-60 is an underground dark matter experiment consisting of apparatus that includes a large jar containing purified water and CF3I, a chemical found in fire extinguishers. The aim of the detector is to search for signs of dark matter particles. When a particle passes through the detector its energy will produce tiny bubbles in the clear liquid.

"It's an underground observatory," explained Fermilab's Hugh Lippincott, who oversaw the installation of the detector. "So it's looking for the same thing in a different way. The only reason why we know about dark matter is from telescopes and satellites, but we don't know what it is. Now we're trying to follow it up, by going underground."

Running since early May, it's already started detecting particles, however, it's yet to find any dark matter. Although COUPP-60 is buried deep in an underground laboratory, the advantage it has over orbital and terrestrial instruments that are searching for dark matter is that it's shielded from the noise of other particles: dark matter passes effortlessly through the Earth, whereas most other particles don't. "We turned it on and saw what we think are alpha particles," Lippincott. told **All About Space**, "It's a radiation detector so we can see dark matter but we can also see neutrons and alphas."

Scientists have been testing COUPP-60 over the last few weeks for its sensitivity and accuracy, and one of the plans is to increase shielding against other particles around the detector by submersing it in over 26,000 litres (7,000 gallons) of water.

It may not have detected any dark matter yet, but the experiment has gone smoothly so far and Lippincott is hopeful that they will be able to confirm a signal from COUPP-60 in the near future. "It would be lovely to detect some signal that was dark matter. Within six months to a year we would not expect to see anything and then after that, who knows?" ●

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Ancient stream discovered on Mars

Curiosity rover finds the remains of an ancient streambed on the Red Planet

NASA's Curiosity rover has found evidence that a rocky outcrop is in fact the remnants of an ancient stream that once flowed through the Gale Crater area. "At a minimum, the stream was flowing at a speed equivalent to a walking pace - one metre or three feet per second," said Rebecca Williams of the Planetary Science Institute in her report. "It was ankle deep to hip deep."

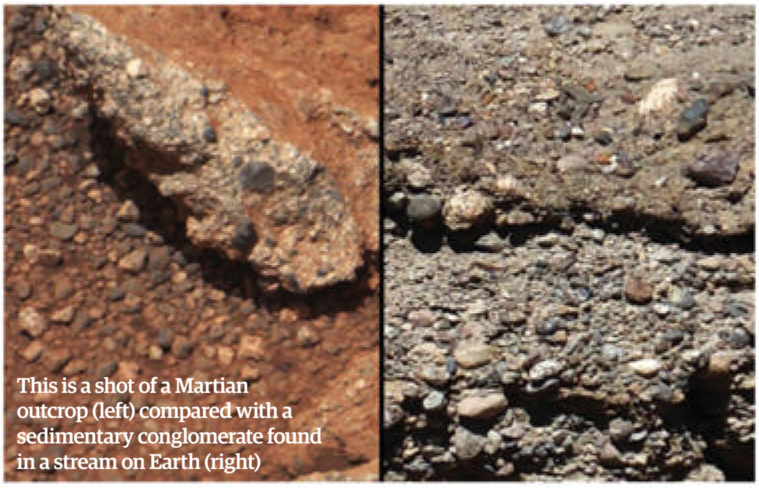
This outcrop, which has been dubbed 'Hottah' after the Hottah Lake in the Canadian Northwest Territories, is the exposed bedrock of a stream that is made up of sedimentary conglomerate - fragments of rock the size of sand grains up to the size of golf balls that have been fused together. Evidence of water activity is in the rounded pebbles within this conglomerate: these pieces of gravel are called clasts and their rounded shape with sandy matrix points indicates that they were transported several kilometres across the surface of Mars by the flow of water.

"The rounding indicates sustained flow," said report co-author Sanjeev Gupta of Imperial College, London. "It occurs as pebbles hit each other multiple times. This wasn't a one-off flow. It was sustained, certainly more than weeks or months, though we can't say exactly how long."

Hottah was one of three outcrops examined by Curiosity's Mastcam that were found between a one and 100-metre (3.3 and 328-foot) radius of the Mars Science Laboratory's landing site. Chemical analysis was also performed using the Chemcam while being blasted by its powerful laser. The report is a result of the rover's findings in its first 40 days on Mars.

"These conglomerates look amazingly like streambed deposits on Earth," Williams explained. "Most people are familiar with rounded river pebbles. Seeing something so familiar on another world is exciting and also gratifying." ●

> "The stream was flowing at a speed equivalent to a walking pace and it was ankle deep to hip deep"



This is a shot of a Martian outcrop (left) compared with a sedimentary conglomerate found in a stream on Earth (right)

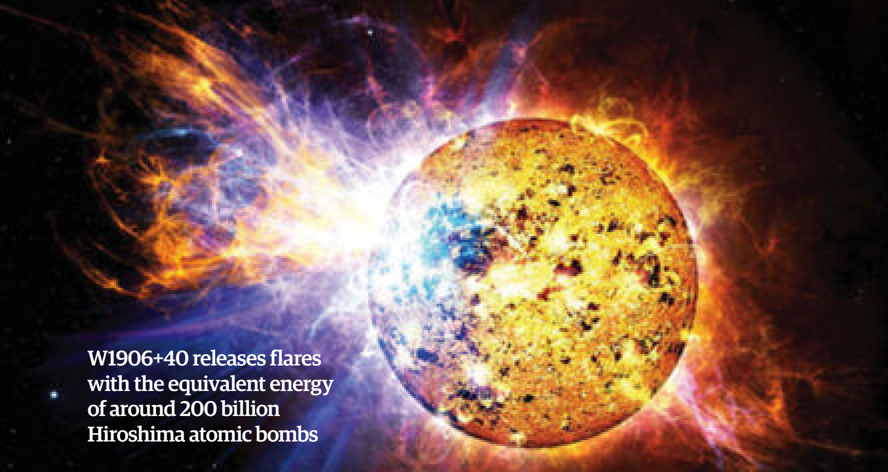
Deadly dwarf star's killer flares

An astronomer working with data from the exoplanet-spotting Kepler spacecraft has revealed the nature of a strange dwarf star 53 light years from Earth. It's an L-type star designated W1906+40 that's smaller than Jupiter, cooler than the Sun and probably around 4 to 5 billion years old. What makes it so unusual is its temperature: in regular intervals of about a week, the star flares up from its standard 2,038 degrees Celsius (3,700 degrees Fahrenheit) to 7,760 degrees Celsius (14,000 degrees Fahrenheit), briefly becoming much brighter, before cooling back down and dimming again.

"We saw these white-light flares, which were a first for such a cool star," said John Gizis of the University of Delaware. "We hope we can use what we're learning to understand our Sun... how flares work there and how magnetic fields in stars behave."

The existence of this type of star also poses a potential risk to life on planets that exist in the same system, rendering nearby planets sterile with their large bursts of radiation.

A recent malfunction with Kepler's telescope means its mission has come to a premature end, although there is a mass of data from the spacecraft still to analyse. ●



W1906+40 releases flares with the equivalent energy of around 200 billion Hiroshima atomic bombs

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Light echoes discovered near supernova

Light from an extremely bright supernova has been discovered echoing off the debris in its local area. Supernova 2009ig exploded four years ago, 127 million light years away in the constellation Cetus and is only the sixth supernova of its kind discovered.

Merger hints at universe's evolution

The HXMM01 system, a pair of galaxies each with a mass of 100 billion Suns, was observed using data from Herschel and caught merging when the universe was 3 billion years old, helping scientists understand how galaxies formed.

Issue 13 correction

We incorrectly printed the name of our second review item from opticalhardware.co.uk on page 95 of issue 13, which should have read 'Ostara Astro SWA70 26mm (2")'. We strive for accuracy on **All About Space** but deadline pressure means mistakes can slip through.

3D printing in space

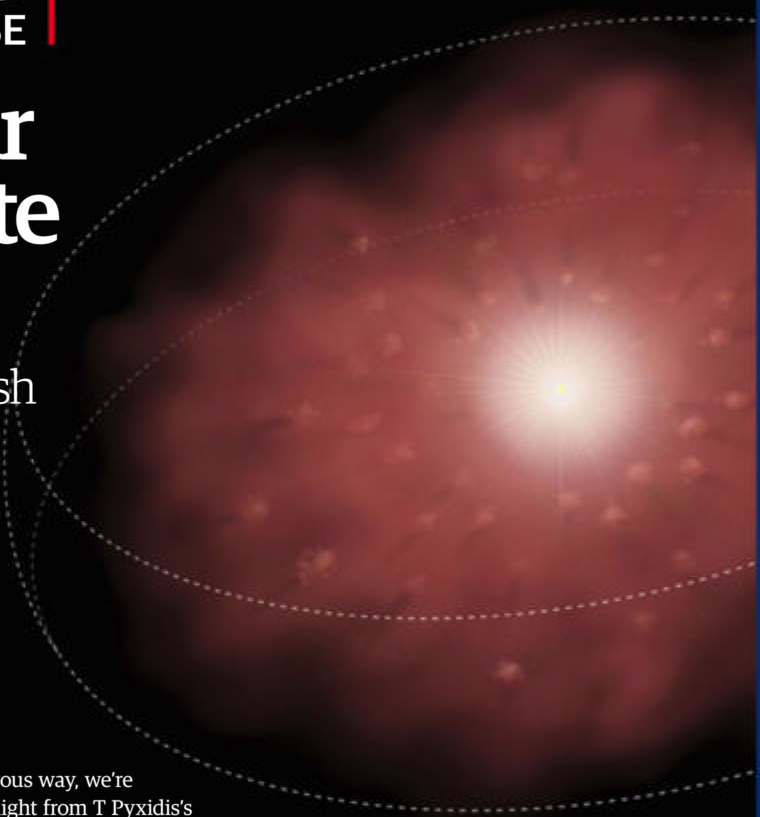
The ESA has sent a printed toolbox to the ISS. The toolbox required stringent tests before being released for use in space, but the advantage of 3D printing items is that if any part breaks, it can immediately be replicated.

Mystery of planet formation solved

Scientists using the European Southern Observatory's Atacama Large Millimeter/submillimeter Array (ALMA) have found a region of space that solves how planets form from dusty discs.

Along with a small team, PhD student Nienke van der Marel was studying a star ringed with dust in the system Oph-IRS 48, 390 light years from Earth, when she found something that caught her eye. "At first the shape of the dust in the image came as a complete surprise to us," van der Marel said. "Instead of the ring we had expected to see, we found a very clear cashew-nut shape. We had to convince ourselves that this feature was real, but the strong signal and sharpness of the ALMA observations left no doubt about the structure."

The team found a dust trap – a region where tiny dust particles were clumping together, moving into high-pressure regions and forming larger and larger objects as they move. Up until now the formation of planets and comets from dust traps has been theory, they've only existed in computer simulations, providing an environment where submicron particles can grow to objects ten times the size of the Earth in just a few million years.



The model of a debris disc around the double star system T Pyxidis, created using the reflected light of a nova

Erupting star used to create 3D map

Hubble uses a stellar flash to create a map of space

A stellar eruption from the nearby double star system T Pyxidis has allowed scientists to create a three-dimensional map of the local area around it. Astronomers have traced a blast from the reoccurring nova during its latest outburst in April 2011 through the ejecta of previous eruptions, using the Hubble Space Telescope's Wide Field Camera 3. As it passed through the system, it lit up the individual parts of the disc of material that surrounds the stars (which is about one light year in diameter) in sequence.

"We've all seen how light from fireworks shells during the grand finale will light up the smoke and soot from shells earlier in the show," explained Hofstra University's Stephen Lawrence, part of the team studying the phenomenon. "In an analogous way, we're using light from T Pyxidis's latest outburst and its propagation at the speed of light to dissect its fireworks displays from decades past."

"We fully expected this to be a spherical shell," explained Arlin Crotts of Columbia University, a member of the research team. "This observation shows it is a disc and it is populated with fast-moving ejecta from previous outbursts."

This stellar 'echo' has also been used to calculate the nova's distance to 15,600 light years from Earth, in the southern hemisphere's Pyxis constellation. Novas like T Pyxidis happen when white dwarves siphoning hydrogen from another star build up so much of the gas that it detonates in a blast equivalent to a colossal nuclear bomb.

Brain Dump: science beyond the boundaries of space

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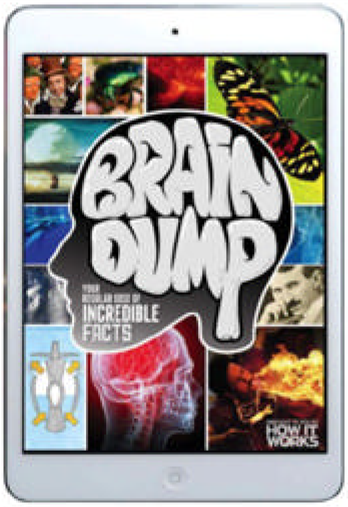
"**Brain Dump** is a milestone product for more than one reason," said Aaron Asadi, Head of Publishing. "This is a brand-new digital publishing initiative that will make everyone sit up and take notice – from its cutting-edge subscription model to the bespoke design and shape of the content."

Dave Harfield, Editor in Chief, added: "Since **How It Works**' rise to dominance, we've worked tirelessly to build on its legacy. **Brain Dump** is very much a result of that passion, aiming to be as entertaining as it is educational. The editorial, design and bold price point make it truly accessible to all and sets a new standard for knowledge/science magazines on iPad and iPhone."

Brain Dump is the latest addition to Imagine's expanding portfolio and a free sample issue will come pre-installed on the app.



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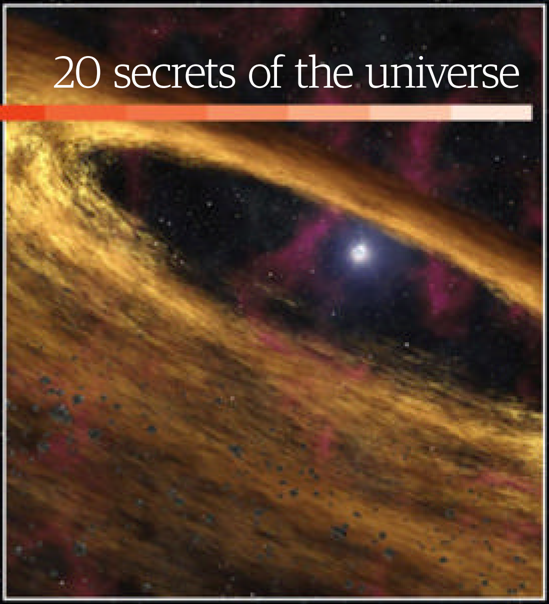
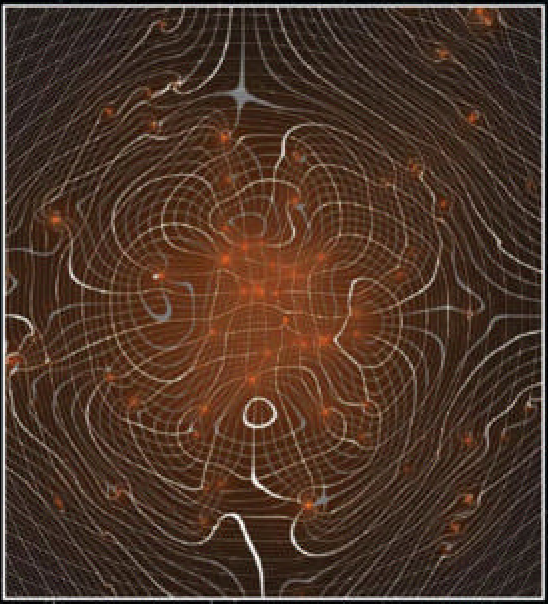
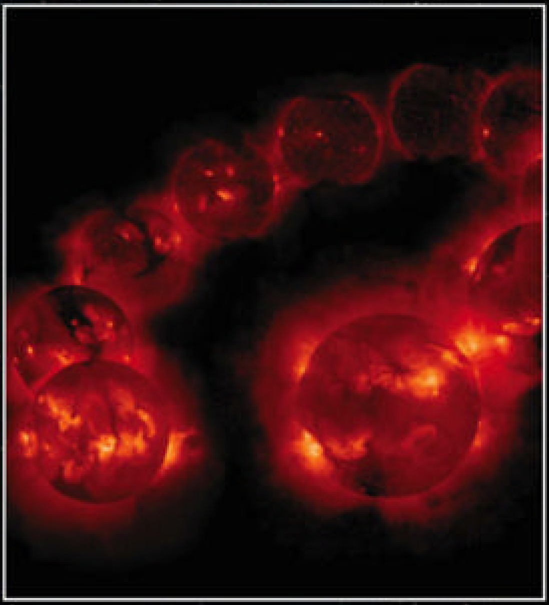




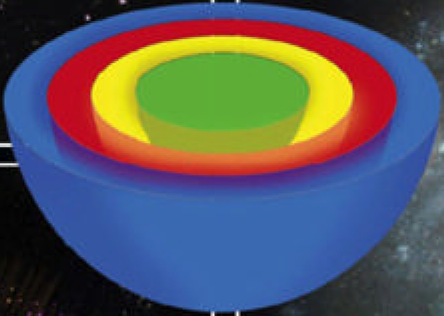


20 Secrets of the universe

Astronomers today know a tremendous amount about the universe – but it still has many questions and mysteries. Here are 20 of the biggest secrets in space…

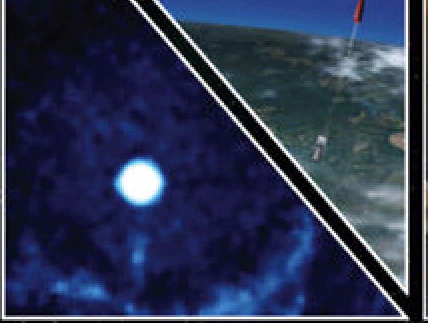
Written by Giles Sparrow

Fermi bubbles have only recently been discovered around galaxies and are still the subject of keen scientific observation



The chemical reactions inside a star that lead to a supernova are difficult to understand

The universe is big beyond imagination and possibly, even science



1 How big is the universe?

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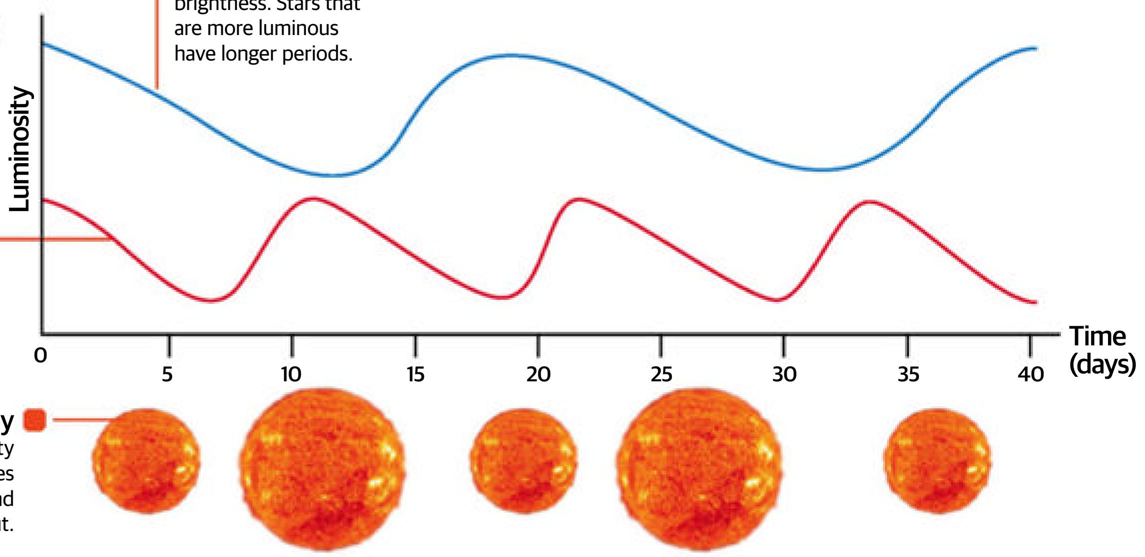
Less than a century ago, most astronomers believed that our Milky Way galaxy, roughly 100,000 light years in diameter, was the entirety of the universe – it was only in the Twenties that Edwin Hubble used rare stars called Cepheid variables to show that the spiral nebulas in the sky were actually independent galaxies millions of light years beyond our own. Since then, the universe has just got bigger and bigger – modern giant telescopes can now see galaxies many billions of light years away.

The main thing that puts a limit on the size of the universe is the limited speed of light, and the fact that it's only had 13.8 billion years to grow since the Big Bang. Any light from objects more than 13.8 billion 'light years' away simply hasn't had time to reach us yet, and this limits our 'observable universe' to a spherical bubble with a radius of 13.8 billion light years, centred on Earth. How far the universe might carry on beyond the observable boundary, though, is still hotly debated.

Standard candles

The best way of measuring the distance to a far-off galaxy is to use a 'standard candle' – a star whose absolute brightness can be predicted, so that its apparent brightness from Earth is directly related to its distance. Hubble's discovery of galaxy distances relied on standard candles known as Cepheid variables, which in turn were discovered by Henrietta Swan Leavitt in 1908.

Cepheids are yellow supergiants, bright enough to spot in other galaxies, that vary in brightness with a well-defined period of several days



Variability
The variability period is related to a Cepheid's average brightness. Stars that are more luminous have longer periods.

Distance
By calculating a Cepheid's intrinsic average brightness and comparing that to its brightness measured from Earth, astronomers can work out its true distance.

Size and energy
Cepheid variability is linked to changes in the star's size and energy output.

A photo of spiral galaxy NGC 3370 in the constellation Leo against a backdrop of distant galaxies. This was shot by the Hubble Space Telescope and was sharp enough for astronomers to identify many individual Cepheid variables

2 What's inside a black hole?

PARTIALLY SOLVED

Most black holes form when a star with a mass of around 20 times the Sun goes supernova. The surviving core, still with a mass of more than five Suns, collapses past the 'neutron star' stage into a singularity

A black hole is an object with such high mass and density that its 'escape velocity' (the speed an object would have to travel to leave its surface) is faster than the speed of light, so that nothing can escape from it. Although the very nature of black holes meant that they were purely theoretical objects for several decades after their first prediction in 1915, since the Seventies astronomers have identified black holes with increasing certainty from the effect they have on their surroundings.

The outer 'surface' of a black hole is called its event horizon, and marks the point at which its escape velocity becomes greater than the speed of light. But the event horizon isn't the surface of a solid object - most astronomers think that objects heavy enough to form black holes (usually the collapsing cores of burnt-out monster stars) have such powerful gravity that they crush their constituents into subatomic smithereens - tiny particles that are known as quarks. These collapse to form an incredibly tiny but dense point known as a singularity, which bends space and time around it in strange ways.

Beyond the singularity

While the standard model of a black hole has a singularity at its heart, that's not the only possibility. In a rotating or 'Kerr' black hole, it's possible to avoid the singularity, and some cosmologists think it might even be possible to travel between two such black holes along a 'wormhole' linking distant regions of space. Other theories are even bolder - in 2013 a group of Russian astronomers suggested that advanced civilisations might be able to exist inside the event horizon of a supermassive black hole, tapping energy from the central singularity. Some cosmologists, meanwhile, have argued that our entire universe might effectively be a giant black hole.

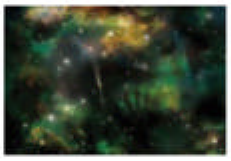
3 How is there water on Jupiter?

SOLVED

In 1995, the Infrared Space Observatory satellite detected signs of water in Jupiter's stratosphere, the uppermost layer of its atmosphere. Jupiter's lower atmosphere appears to be dry, and while models of its internal structure predict large amounts of water beneath the clouds, cold layers above should prevent it from 'leaking out'. In 2013, the Herschel Space Observatory mapped Jupiter's water signature and found that it is concentrated over regions that were in the firing line when Comet Shoemaker-Levy 9 hit Jupiter in 1994. While the visible scars from this cosmic crash have long since faded, the comet seems to have left a lasting impression!

4 The origins of gamma-ray bursts

PARTIALLY SOLVED



High-energy gamma ray bursts (GRBs) from space were discovered in the late-Sixties by satellites designed to monitor nuclear tests on Earth. They seem to come from far beyond our Milky Way galaxy, but it was only in 1998 that a GRB was finally linked to the flare of a supernova in a faint distant galaxy for the first time. Today it seems that most bursts come from supernovas, but a substantial minority come from neutron stars colliding and merging to form black holes. However, the mechanism that produces the gamma rays, and focuses them into tight beams that can cross billions of light years of space to Earth, is still not fully understood.

Asteroid belt
A handful of faint comets have short orbits that remain within the asteroid belt. Frequent passages round the Sun have burnt away most of their surface ice.

5 Where comets come from

PARTIALLY SOLVED

Bright comets are rare but spectacular visitors to Earth's skies, so it's little wonder they made an impression on our ancestors. For centuries, people thought they were atmospheric phenomena, but in 1577, Danish astronomer Tycho Brahe showed for the first time that comets lay far beyond the Moon. Then in 1705, Edmond Halley computed the path of the comet that bears his name, predicting that it took around 76 years to orbit the Sun in a highly stretched or elliptical orbit.

6 What is the aurora borealis?

SOLVED

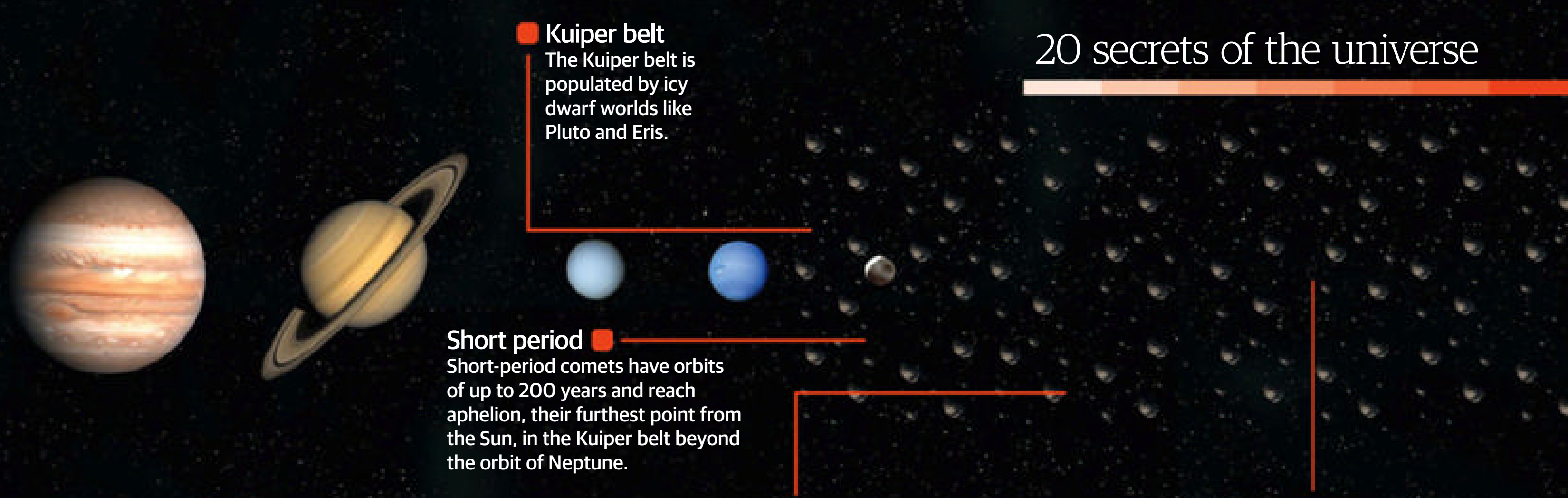
The beautiful glow of the northern lights is one of the most entrancing spectacles in the night sky - though it's one that's rarely visible across most of the UK. Many of the early theories that tried to explain these shimmering patterns of light viewed them as an unusual type of weather, and it was not until 1900 that Norwegian scientist Kristian Birkeland suggested that the auroras were created by particles from the solar wind entering the Earth's atmosphere.

Unfortunately, Birkeland's specific theory was wrong, and it was not until the dawn of the space age that astronomers and geophysicists first began to understand the true nature of how the auroras are created. American scientist James Van Allen pioneered the study of Earth's magnetosphere using instruments carried aboard early NASA satellites to discover the Van Allen radiation belts of fast-moving, high-energy particles, that surround the Earth.

Thanks to the work of Van Allen and others, we now understand that the auroras are created by the interaction of our planet's magnetic field with that of the Sun itself, carried across the Solar System on the solar wind. This allows some energetic particles to slip down Earth's magnetic field lines in 'auroral ovals' around each pole. About 80 kilometres (50 miles) above the ground, these particles strike atoms of nitrogen and oxygen in the thin upper atmosphere, temporarily boosting their energy. As the atoms return to their normal state, they release excess energy in the form of light with characteristic wavelengths - the most common auroral colours are green or brownish red (from oxygen) and blue or red (from nitrogen).

But even if we understand the mechanism behind the lights themselves, the auroras still have mysteries. For example, there are anecdotal reports of sounds such as claps and crackles accompanying auroras. Researchers were sceptical, but in 2012 a Finnish team succeeded in recording the sounds for the first time. What causes them, however, remains unknown.

The northern lights put on a spectacular display above the wintry landscape of Alaska's Bear Lake region. The intense green light is emitted from excited oxygen atoms 80 kilometres (50 miles) up in Earth's atmosphere



Kuiper belt
The Kuiper belt is populated by icy dwarf worlds like Pluto and Eris.

Short period
Short-period comets have orbits of up to 200 years and reach aphelion, their furthest point from the Sun, in the Kuiper belt beyond the orbit of Neptune.

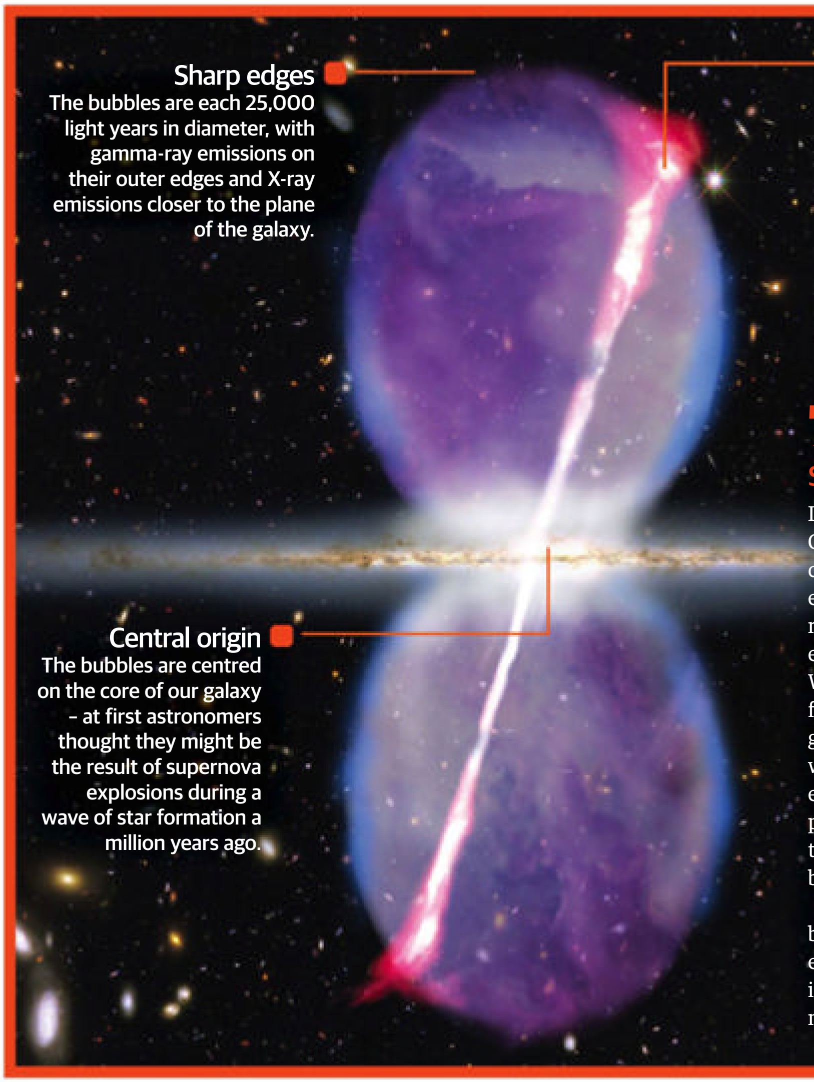
Halley's Comet
Halley's comet spends most of its time here. It was diverted from a long-period orbit by a close encounter with Jupiter several thousand years ago.

Oort cloud
Most comets follow orbits that last many thousands of years, and have aphelion points in the Oort cloud at the outer edge of the Solar System.

Today we recognise that most comets follow elliptical paths. Some, like Halley's, have relatively short orbital periods and reach their most distant point from the Sun a little way beyond the orbit of Neptune, amid the region known as the Kuiper belt. Other comets have much longer periods and may travel hundreds of times further from the Sun. Occasional rare visitors are not in orbit around the Sun at all - they are rogue interstellar comets that make a single pass through our Solar System.

In 1950, Jan Oort realised that the orbits of long-period comets suggested they were coming from a huge cloud surrounding the Solar System at a distance of 20,000 AU or more. Even though we can't see this cloud, we now think it's the origin of all the Solar System's native comets, and was probably created when the planets 'kicked out' comets from closer to the Sun early in the Solar System's history. Today, encounters with giant planets can pull long-period comets back into shorter-period orbits.

> "Even though we can't see this cloud, we now think it's the origin of all the Solar System's native comets"



Sharp edges
The bubbles are each 25,000 light years in diameter, with gamma-ray emissions on their outer edges and X-ray emissions closer to the plane of the galaxy.

Black hole jet
The discovery of a gamma-ray jet linking the bubbles to the locality of our galaxy's central black hole confirmed that they are almost certainly linked to a burst of recent activity from around it.

Central origin
The bubbles are centred on the core of our galaxy – at first astronomers thought they might be the result of supernova explosions during a wave of star formation a million years ago.

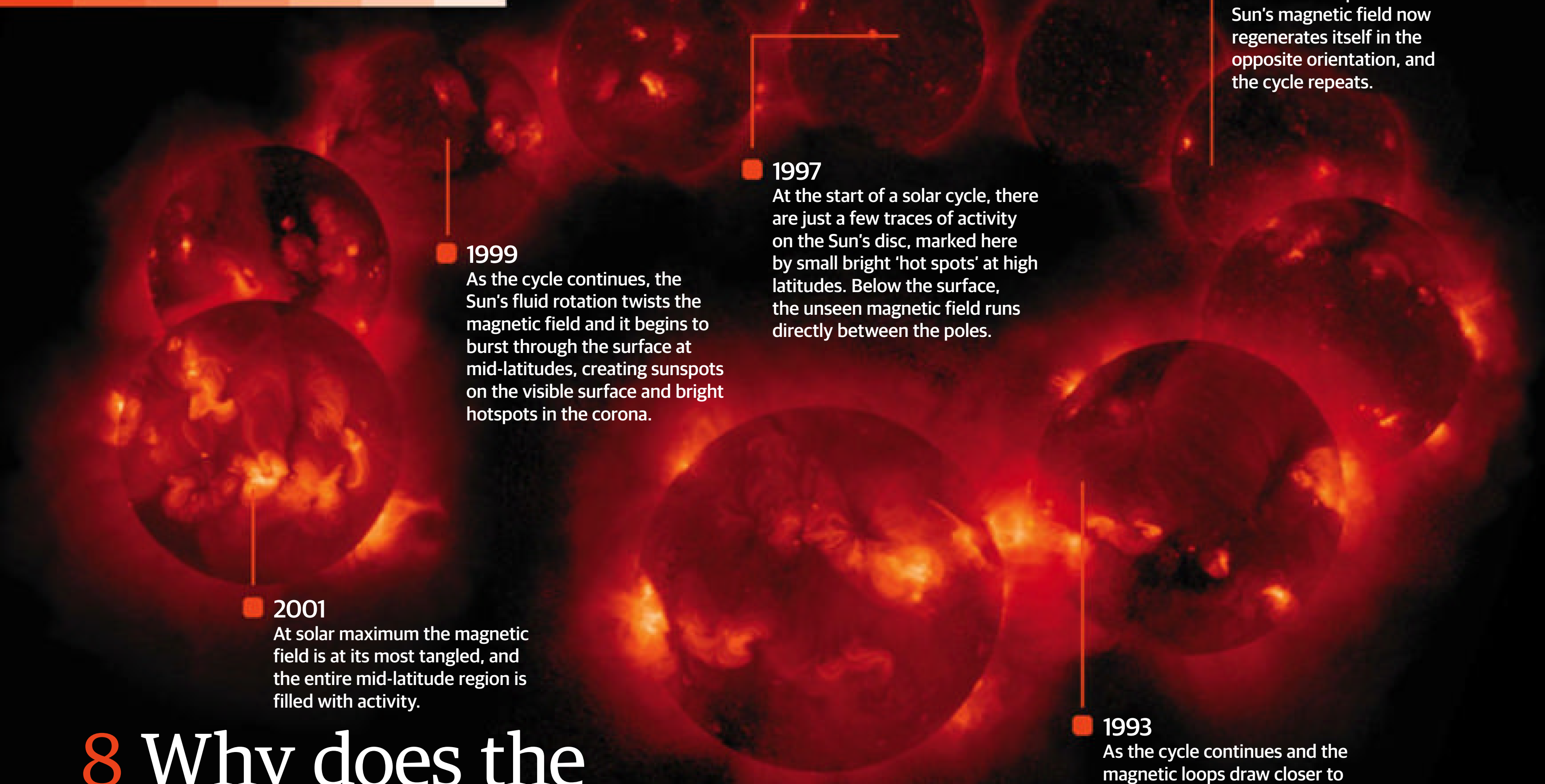
7 What are Fermi bubbles?

SOLVED

In 2010, a team using the Fermi Gamma-ray Space Telescope discovered two huge bubbles of high-energy gamma-ray emission, each roughly 25,000 light years in diameter, extending above and below the Milky Way. The bubbles had been hidden from view by an intervening 'haze' of gamma rays from nearby space, and when a team working on models to explain the haze developed a way of peering through it for the first time, they found the enormous 'Fermi bubbles' that lie beyond.

The well-defined structure of the bubbles and the strength of their emissions suggest they were formed in a single rapid event, perhaps a few million years ago, close to the crowded centre of our Milky Way galaxy. Since then, they've ballooned outward into the mostly empty regions of the galactic halo. Despite appearances, they really are thin-walled bubbles of gamma-ray emitting material, rather than filled-in clouds.

The discovery of a gamma-ray-emitting jet linking the bubbles to the centre of our galaxy provided crucial evidence for the event that created them - a burst of activity from the supermassive black hole at the centre of the galaxy. This invisible monster is normally starved of material - but when a stray gas cloud or larger object passed nearby, it seems that it belched out bubbles of stray hot gas as it gobbled down a rare meal.



1997
At the start of a solar cycle, there are just a few traces of activity on the Sun's disc, marked here by small bright 'hot spots' at high latitudes. Below the surface, the unseen magnetic field runs directly between the poles.

1999
As the cycle continues, the Sun's fluid rotation twists the magnetic field and it begins to burst through the surface at mid-latitudes, creating sunspots on the visible surface and bright hotspots in the corona.

2001
At solar maximum the magnetic field is at its most tangled, and the entire mid-latitude region is filled with activity.

1993
As the cycle continues and the magnetic loops draw closer to the equator from each side, they start to cancel out and activity begins to fade.

1995
By the end of the cycle only a little activity persists close to the equator. The Sun's magnetic field now regenerates itself in the opposite orientation, and the cycle repeats.

8 Why does the Sun have cycles?

PARTIALLY SOLVED

The solar cycle was discovered in 1843 by German astronomer Samuel Heinrich Schwabe, following years of carefully observing dark sunspots on the surface of the Sun. He found that sunspots start each cycle in small numbers at relatively high latitudes on either side of the Sun's equator, increase in numbers as they moved towards the equator, and then fade away as they reached the lowest latitudes, before reappearing at high latitudes once again. At first glance, the cycle appears to repeat every 11 years, but measurements of the magnetism of the spots shows that their north-south polarities reverse with each cycle, so the entire sunspot cycle takes 22 years to complete. Since the cycle was discovered, it's also become clear that it affects many other aspects of solar activity, with solar flares, X-ray emissions and violent 'coronal mass ejections' all at their peak around the same time as the sunspot maximum.

The cycle is driven by changes in the solar magnetic field, which is created by electric currents flowing in the upper layers of the Sun's atmosphere. At the start of each cycle, the magnetic field is neatly aligned from pole to pole, but the Sun's rotation causes its fast-spinning equator to drag the field around the Sun until it becomes tangled. Tangles and loops in the magnetic field are responsible for the sunspots and other activity. While this basic mechanism is understood, astronomers are still struggling to understand how solar cycles can vary hugely in intensity and sometimes even disappear completely for several decades.

9 Are there more than three dimensions?

PARTIALLY SOLVED

We know for certain that there are at least four dimensions: Einstein's theories of relativity treat time as another dimension that interacts with the three dimensions of space to create a four-dimensional 'space-time manifold'. In extreme situations (for example when objects travel at close to the speed of light, or around massive objects), different parts of the manifold can be 'traded off', so that for instance space dimensions become shorter while time is stretched.

This might sound strange, but it's been proven by countless experiments. The more intriguing issue is whether there might be more dimensions than those four. Particle physicists who try to explain the various subatomic particles and fundamental forces that control the universe hope to unify all of physics with a single model known as a 'string theory'. The idea is that all particles are tiny vibrating loops or strings of energy, 'humming' like violin strings, and forming different 'harmonics' that determine the properties they exhibit. The big catch with this neat idea is that the strings need to vibrate in either 26 dimensions (for traditional string theory), or ten (for so-called superstring theories).

The idea that there could be other dimensions beyond the ones that we're familiar with seems mind-boggling – where are they? One idea is that they might be curled up on themselves at tiny scales, so they are invisible in normal situations. Another idea is that our four-dimensional universe is 'afloat' in a wider multi-dimensional cosmos that lies beyond our perceptions.

10 How galaxies hold themselves together

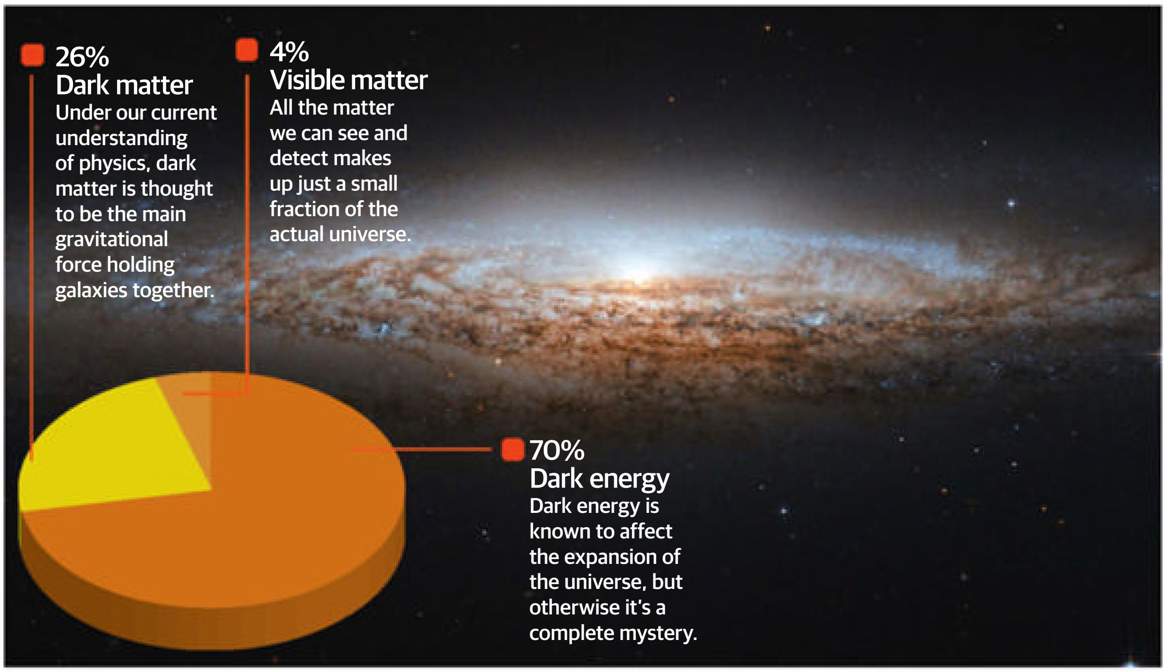
UNSOLVED

The discovery of galaxies other than our own Milky Way was an important one, providing us with evidence for a huge and expanding universe. One of the consequences of this discovery, however, was that galaxies appeared to be breaking the laws of physics. They are spinning so fast that the gravitational power of their observable matter is not enough to hold them together. They should be tearing themselves apart and flinging matter into space. So, why is this not the case?

The answer lies in one of the most controversial unsolved mysteries of the universe. Scientists believe that there is some hidden matter at work holding galaxies together, rendered invisible to our modern instruments but pervading the entire universe in such a way that, in fact, there is much more of it than matter itself.

As you may have guessed, we're talking about dark matter, the mysterious invisible matter that we've been trying to detect for decades. We're getting closer, but we still don't have direct evidence it exists. Dark matter does not interact with the electromagnetic force, making detection incredibly difficult.

The matter we know of accounts for just 4% of the universe. Dark matter makes up 26% of the universe, with dark energy (a force present in the entire universe but with no gravitational effects) making up 70%. Dark matter appears to have a gravitational effect on visible matter, which would be why galaxies can hold themselves together. If we can uncover this secret, it could be the biggest discovery in modern science.



26%
Dark matter
Under our current understanding of physics, dark matter is thought to be the main gravitational force holding galaxies together.

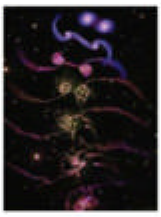
4%
Visible matter
All the matter we can see and detect makes up just a small fraction of the actual universe.

70%
Dark energy
Dark energy is known to affect the expansion of the universe, but otherwise it's a complete mystery.

According to Einstein's theories of relativity, space-time is a four-dimensional manifold. In extreme situations of relative motion or high gravity, the dimensions can become 'twisted' relative to our frame of reference, creating strange distortions of space and time

11 How black holes are linked to galaxies

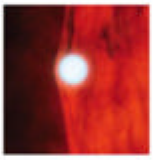
PARTIALLY SOLVED



In 2011, astronomers discovered a 'naked quasar' – a supermassive black hole with no 'host galaxy'. Jets of material from the quasar seem to be generating stars in a neighbouring galaxy. The two objects will eventually collide and produce an 'active galaxy', but is this rare or the way in which all galaxies form?

12 Why light bends

SOLVED



Rays of light bend as they pass close to massive objects because of general relativity. Einstein's theory explains that 'space-time' is distorted by massive objects. It's as if space were a sheet with bowling balls creating dents in some areas – if you rolled a pool ball across the sheet in a straight line, its path would be deflected as it passed close to the more massive objects.

13 What is space roar?

UNSOLVED

In 2008, a NASA team's attempt to detect the very first stars ended up discovering something even more intriguing – mystery radio waves from deep space. So far they've ruled out an origin in or around our own Milky Way galaxy, and there simply aren't enough distant radio galaxies to generate such a powerful signal – so what could be causing it?

"Centimetre-scale dust particles coalesced to form kilometre-sized bodies called planetesimals"

14 How was the Solar System formed?

PARTIALLY SOLVED

The first scientific explanation for the origins of the Earth, Sun and other planets was put forward by Swedish philosopher Emanuel Swedenborg in 1734. Expanded on by Immanuel Kant and Pierre-Simon Laplace later in the 18th Century, this so-called 'nebular hypothesis' suggested that the Solar System formed from the collapse of clouds of interstellar material into a spinning, flattened disc, out of which planets grew as particles coalesced.

Laplace's version of the theory dominated 19th Century astronomy, but was temporarily undermined in the 20th Century. In its place, astronomers put forward a range of alternatives, including theories that the planets had been captured into orbit around the Sun, that a stream of planet-forming material had been ejected from the Sun in a huge eruption, or even that the planets had been torn from our star by tides from a passing star.

All of these rival theories had their own problems, however, and in the Seventies Soviet astronomer Victor Safronov produced a widely accepted modern version of the Laplace theory, known as the Solar Nebular Disc Model. This resolved many of the problems by suggesting that the planets began their formation in an 'accretion disc' orbiting the newborn Sun. Here, centimetre-scale dust particles coalesced to form kilometre-sized bodies called planetesimals, which then collided to form larger bodies. Once some planetesimals grew large enough to have substantial gravity, they pulled in other material and grew rapidly in a process called 'runaway accretion'. Finally, the planetesimals collided with each other to form full-blown 'protoplanets'. Differences between the inner rocky planets and the outer gas giants can be explained by variations in temperature and chemistry across the original nebula, but there are still some unsolved questions – not least how the small dust particles formed into the first planetesimals.

15 How the universe began

SOLVED

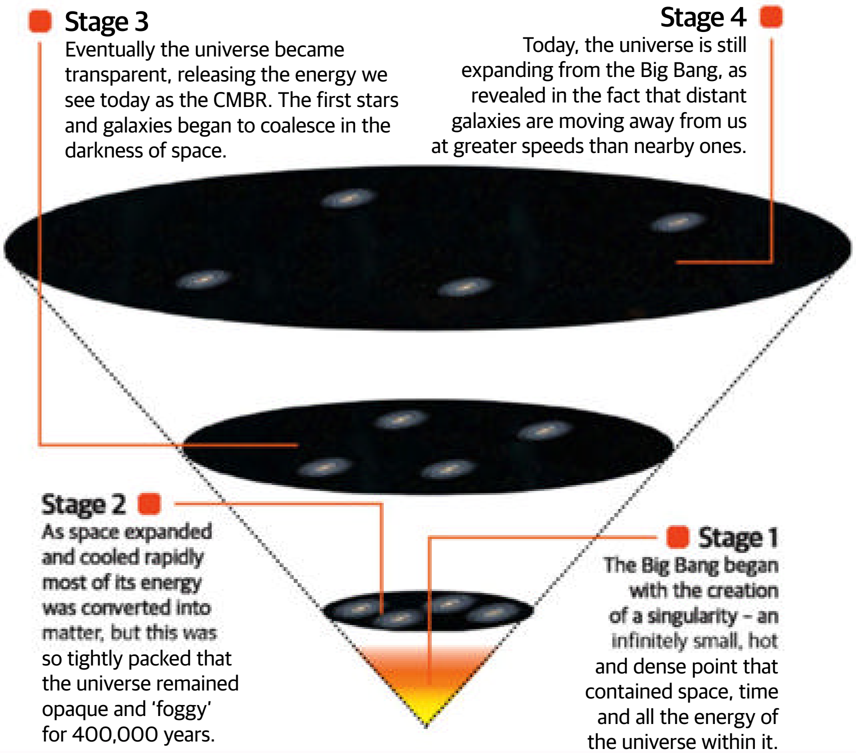
Until about a century ago, most people were divided between the Biblical account of the universe as a few thousand years old, and the scientific evidence that the Earth and Sun were many millions, even billions, of years old. But when Edwin Hubble measured the distance to the closest galaxies in the Twenties, he also discovered that more distant galaxies are moving away from Earth more quickly. The entire universe is expanding, and pulling galaxies away from each other.

In 1930, Belgian priest Georges Lemaître pointed out that all the material in the universe must once have been concentrated in a much smaller volume. He referred to this idea of a cosmic origin as the 'primeval atom', but it divided the scientific establishment at the time.

Then, following breakthroughs in nuclear physics, it became clear that the extreme conditions of Lemaître's early hot, dense universe could have spontaneously created all the matter in the universe in just the right proportions to match our observations. Fred Hoyle, an ardent supporter of the rival 'steady state' theory, dismissed the primeval atom as nothing but a "big bang", and the name stuck.

The clinching evidence came in 1964, when Arno Penzias and Robert Wilson discovered an unexpected glow of microwave radiation coming from the sky. Corresponding to a temperature of just 2.7°C (36°F) above absolute zero, this Cosmic Microwave Background Radiation (CMBR) fitted perfectly with predictions for the 'afterglow' of the Big Bang.

Even though no other theory could explain the CMBR, there were still problems with the Big Bang – primarily the apparent 'smoothness' of the universe. In 1980, Alan Guth introduced inflation – the idea that a fraction of a second after the Big Bang, one small, uniform region of the infant cosmos was blown up to form the universe. Final confirmation that inflation was right came with the discovery of 'ripples' in the CMBR, while measurements from the Hubble Space Telescope have given the universe an age of 13.8 billion years.



Stage 3
Eventually the universe became transparent, releasing the energy we see today as the CMBR. The first stars and galaxies began to coalesce in the darkness of space.

Stage 4
Today, the universe is still expanding from the Big Bang, as revealed in the fact that distant galaxies are moving away from us at greater speeds than nearby ones.

Stage 2
As space expanded and cooled rapidly most of its energy was converted into matter, but this was so tightly packed that the universe remained opaque and 'foggy' for 400,000 years.

Stage 1
The Big Bang began with the creation of a singularity – an infinitely small, hot and dense point that contained space, time and all the energy of the universe within it.

The giant Tunguska explosion knocked down an estimated 80 million trees

16 What caused the Tunguska explosion?

PARTIALLY SOLVED

On 30 June 1908, a huge explosion rocked an area in what is now Krasnoyarsk Krai, Russia, flattening an area covering around 2,000 square kilometres (770 square miles).

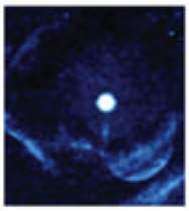
The cause of the event was believed to be a large meteoroid or comet fragment as big as 100 metres (330 feet) wide exploding over five kilometres (three miles) above the Earth. The huge explosion, 1,000 times more powerful than the atomic bomb dropped on Hiroshima, Japan, in World War II, is the largest recorded impact event in Earth's history.

However, the event left few traces of an impact. Aside from the huge flattened expanse, there was no noticeable impact crater and, to date, no fragments of the meteorite have been confirmed. Therefore, the exact cause of the event remains a mystery.

Eyewitnesses living nearby described a huge flash of light and a deafening crack, but no conclusive evidence has yet been found for a meteorite impact. Other theories range from a chunk of antimatter falling from space to a mini black hole passing through the Earth. It's unlikely that we'll ever know for sure what happened, but further studies could help prepare us for a similar impact event in the future.

17 What are recurrent novas?

SOLVED



Recurrent novas are rare stars that appear dim, but occasionally flare up in brilliant eruptions. After a few weeks they subside, but they may flare back into life again years later. They are thought to be close binary stars in which a burnt-out white dwarf is pulling gas away from its companion star.

18 How the asteroid belt formed

SOLVED

Astronomers used to think that the large 'gap' between Mars and Jupiter should be home to a planet. Then, after finding asteroids there, they decided the planet must have been destroyed in some ancient cataclysm. It seems likely that there was once much more material here, but that Jupiter's gravity prevented it from forming a planet.

19 Why is gravity so weak?

UNSOLVED

Gravity is the only force capable of making its presence felt across the vastness of intergalactic space, but compared to the other fundamental forces of physics – electromagnetism and the weak and strong nuclear forces – it's remarkably weak. No one's quite sure why, but it suggests a fundamental difference between gravity and the other forces.

When a star explodes it produces huge shockwaves of material

20 Why do stars explode?

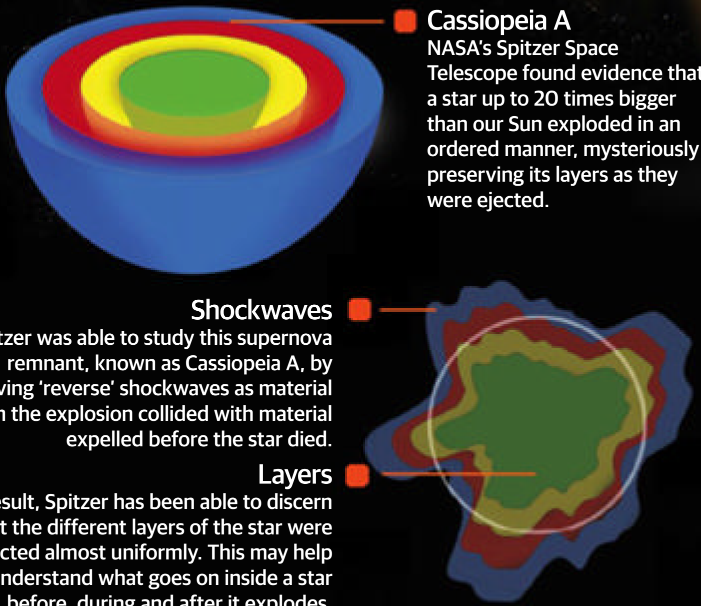
PARTIALLY SOLVED

When an enormous star runs out of fuel, it can no longer support its own gravity and explodes in a huge fireball known as a supernova. We've been attempting to observe and study these giant cosmic explosions for decades and, while we're finally starting to understand their cause, there are still many things we're yet to learn.

There are two predominant types of supernova. The first, Type Ia, occur when a white dwarf accretes material from a larger stellar companion, passing a critical mass and ultimately exploding. Meanwhile Type II supernovas, also known as core collapse scenarios, are the types mentioned earlier, when a giant star runs out of fuel and collapses, resulting in a huge explosion.

Observations of supernovas and simulations in supercomputers have helped us understand what happens when these stars explode but, as of yet, we're not entirely sure when or why they occur. For Type II supernovas in particular, the exact moment at which the explosion will occur is almost impossible to determine. For example the red supergiant Betelgeuse, over 600 light years from Earth, is known to be close to going supernova but we're not sure when. It could explode while you're reading this article, or it may explode in a million years' time.

It is hoped that by studying more and more of these cosmic explosions we'll be able to definitively determine when they will occur. For now, we can only hope that we get the chance to observe one when it does happen.



Cassiopeia A
NASA's Spitzer Space Telescope found evidence that a star up to 20 times bigger than our Sun exploded in an ordered manner, mysteriously preserving its layers as they were ejected.

Shockwaves
Spitzer was able to study this supernova remnant, known as Cassiopeia A, by observing 'reverse' shockwaves as material from the explosion collided with material expelled before the star died.

Layers
As a result, Spitzer has been able to discern that the different layers of the star were ejected almost uniformly. This may help us understand what goes on inside a star before, during and after it explodes.

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SOAR mini-shuttle

An ambitious Swiss company has come up with a novel and incredibly economic concept to launch satellites into orbit by 2017

Written by Ben Biggs

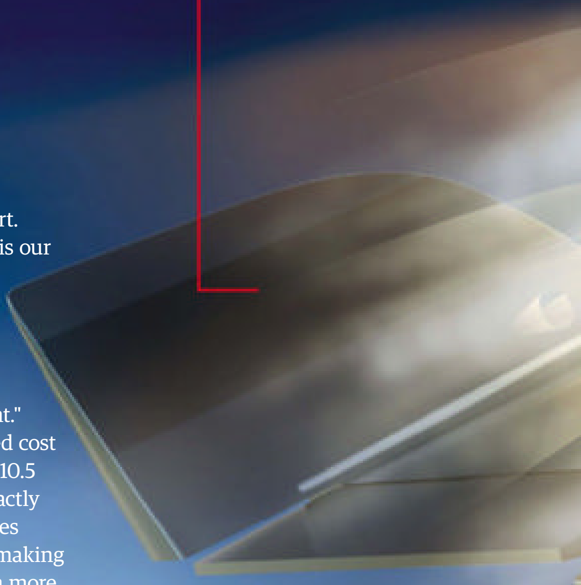
S3 (otherwise known as Swiss Space Systems) is based in the western part of Switzerland and was founded in 2012 by military pilot and mechanical engineer Pascal Jaussi. Its motto is 'Space for all' and one of its ambitious goals is to open a space port by the year 2015 then start test-launching by 2017. S3 is aiming to put small satellites of up to 250 kilograms (551 pounds) into a standard satellite orbit in conjunction with various partners that include the European Space Agency. But the cool bit isn't what S3 plans to do, it's how this private company is going to do it.

Using a zero-g certified Airbus A300, an unmanned mini-shuttle will be piggy-backed to an altitude of around 10,000 metres (33,000 feet) where it will separate from its carrier. Then, once its parent vehicle is at a safe distance, the mini-shuttle will ignite its kerosene and liquid oxygen rockets to boost itself to a target altitude of 80 kilometres (50 miles) above the Earth.

Once it has reached its desired altitude, the mini-shuttle will initiate the third stage of the launch, in which it will open its cargo bay doors and launch the satellite. The satellite is equipped with a rocket engine of its own and can fly the rest of the way to the 700-kilometre (434-mile) altitude orbit, while the mini-shuttle will glide back to Earth after its suborbital flight.

The development costs for the SOAR mini-shuttle are estimated at around 200 million Swiss Francs ($211 million/£140 million) with another 50 million Swiss Francs ($53 million/£35 million) paying for the construction of the space port.

"A big asset of the project is our network of international partners, who all support S3", Pascal Jaussi told **All About Space**, "This enables us to save time and money on research and development." Each launch has an estimated cost of 10 million Swiss Francs ($10.5 million/£6.9 million): not exactly peanuts but it's still four times cheaper than current costs, making the launch of satellites much more accessible. No fuel is required for the landing of the mini-shuttle and there are few disposable flight components, so unlike previous shuttle launch technology, the main elements of the mini-shuttle system can be reused for the next launch, only the satellite launcher is not reuseable.



Piggy-back
The mini-shuttle will ride on the back of an A300 to 10km (33,000 feet) before separating.

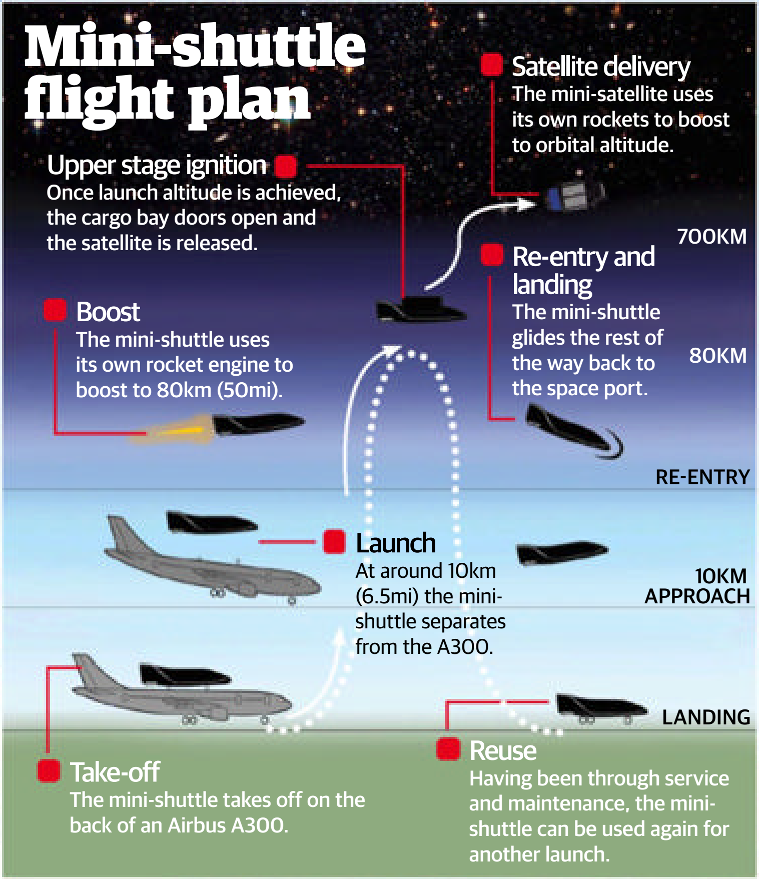
The strangely extra-terrestrial-looking front view of the mini shuttle

Fuel
A liquid oxygen and kerosene engine will blast the mini-shuttle to 80km (50 miles) above the Earth.

The unmanned mini-shuttle will approach the boundary of space to release a mini-satellite into orbit

> "No fuel is required for the landing of the mini-shuttle and there are few disposable flight components"

Mini-shuttle flight plan



Upper stage ignition
Once launch altitude is achieved, the cargo bay doors open and the satellite is released.

Satellite delivery
The mini-satellite uses its own rockets to boost to orbital altitude.

Boost
The mini-shuttle uses its own rocket engine to boost to 80km (50mi).

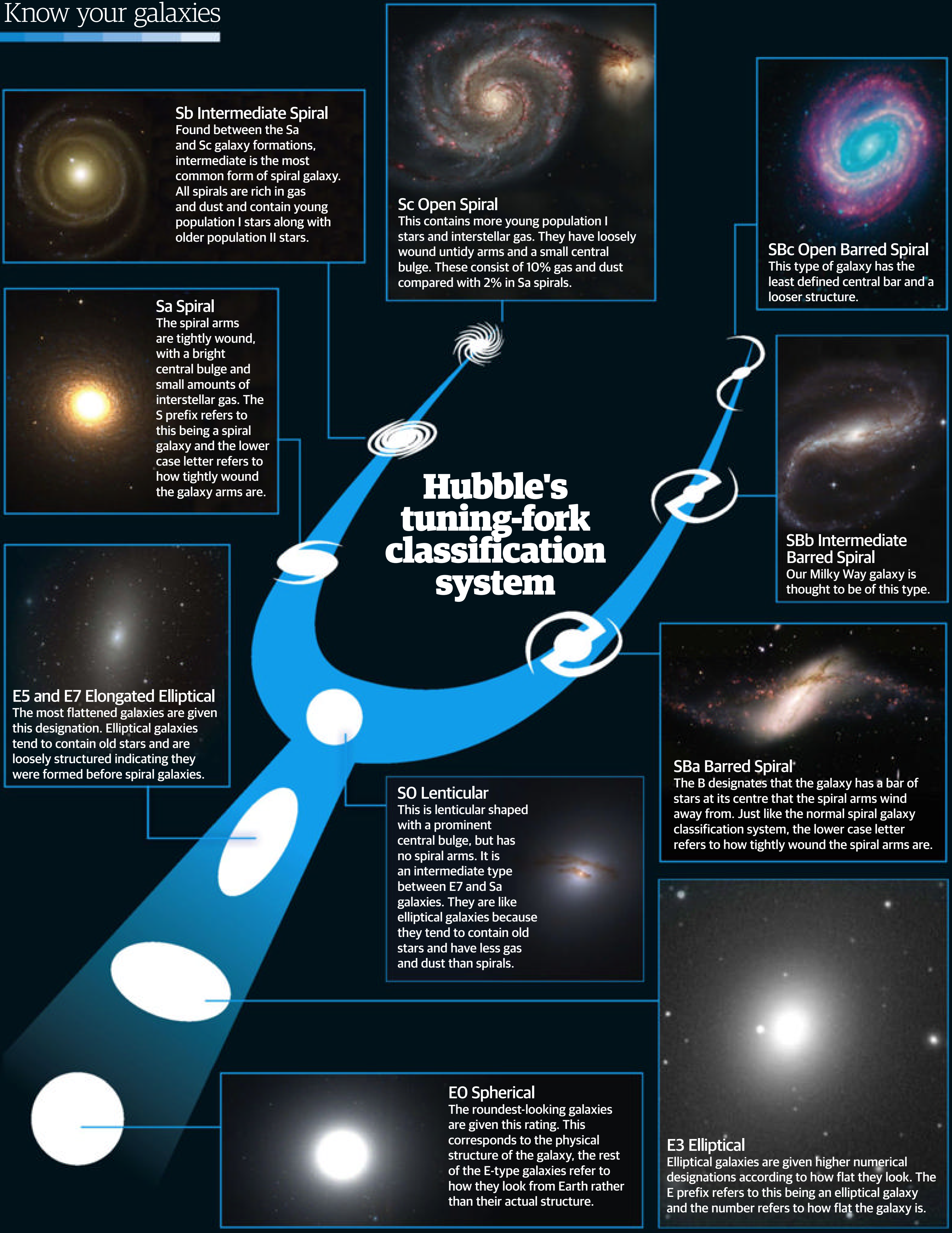
Re-entry and landing
The mini-shuttle glides the rest of the way back to the space port.

Launch
At around 10km (6.5mi) the mini-shuttle separates from the A300.

Take-off
The mini-shuttle takes off on the back of an Airbus A300.

Reuse
Having been through service and maintenance, the mini-shuttle can be used again for another launch.

© Adrian Mann; Swiss Space Systems



Hubble's tuning-fork classification system

E0 Spherical
The roundest-looking galaxies are given this rating. This corresponds to the physical structure of the galaxy, the rest of the E-type galaxies refer to how they look from Earth rather than their actual structure.

E3 Elliptical
Elliptical galaxies are given higher numerical designations according to how flat they look. The E prefix refers to this being an elliptical galaxy and the number refers to how flat the galaxy is.

E5 and E7 Elongated Elliptical
The most flattened galaxies are given this designation. Elliptical galaxies tend to contain old stars and are loosely structured indicating they were formed before spiral galaxies.

S0 Lenticular
This is lenticular shaped with a prominent central bulge, but has no spiral arms. It is an intermediate type between E7 and Sa galaxies. They are like elliptical galaxies because they tend to contain old stars and have less gas and dust than spirals.

Sa Spiral
The spiral arms are tightly wound, with a bright central bulge and small amounts of interstellar gas. The S prefix refers to this being a spiral galaxy and the lower case letter refers to how tightly wound the galaxy arms are.

Sb Intermediate Spiral
Found between the Sa and Sc galaxy formations, intermediate is the most common form of spiral galaxy. All spirals are rich in gas and dust and contain young population I stars along with older population II stars.

Sc Open Spiral
This contains more young population I stars and interstellar gas. They have loosely wound untidy arms and a small central bulge. These consist of 10% gas and dust compared with 2% in Sa spirals.

SBa Barred Spiral
The B designates that the galaxy has a bar of stars at its centre that the spiral arms wind away from. Just like the normal spiral galaxy classification system, the lower case letter refers to how tightly wound the spiral arms are.

SBb Intermediate Barred Spiral
Our Milky Way galaxy is thought to be of this type.

SBc Open Barred Spiral
This type of galaxy has the least defined central bar and a looser structure.

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Galaxy classification

Edwin Hubble's monumental discoveries revealed that the universe consists of a variety of vast galaxies that exist far beyond our Milky Way galaxy.

Edwin Hubble can be ranked as one of the great astronomers, whose discoveries are as important as those of Nicolaus Copernicus and Galileo Galilei.

In 1919, he began working at the Mount Wilson Observatory in California. A few years later, he used the newly built 2.5-metre (100-inch) Hooker Telescope to study Cepheid variable stars located in spiral nebulas. From these observations, he found that they must exist far beyond the Milky Way. In 1925, he presented his finding that these nebulas are galaxies in their own right, proving that the Milky Way is just a small part of the universe as opposed to the existing view that nothing existed beyond it.

Another major discovery was that the spectra of the light emitted by galaxies shifted towards the blue end of the spectrum if they were moving towards the Earth and that those moving away from the Earth showed a shift to the red end of the spectrum. From studying 18 galaxies, Hubble determined that the further away the galaxy is the faster it is moving away from us, which became known as Hubble's Law. From his measurements he reasoned that 2 billion years ago the universe began in a single burst of energy and has been moving away from this point of origin ever since. Today, it is thought the universe began 13.77 billion years ago but this was an important foundation for the influential Big Bang theory.

In 1926, Hubble created his morphological classification of the different types of visible galaxies. He divided galaxies into three major groups that he arranged in his famous Hubble tuning fork diagram. Elliptical galaxies represent over half the visible galaxies and are given the prefix E, while a number from 0 to 7 denotes how round or oval they are. Giant ellipticals exist at the centre of galactic clusters that can contain billions of stars, though there are also dwarf elliptical galaxies that contain a few hundred thousand stars.

Spiral galaxies

Spiral galaxies are equally divided between spirals with a central bulge (S types) and spirals with a central bar (SB types). Stars form in the spiral arms and centres of these galaxies. A further designation running from a to c was given to indicate how tightly or loosely wound the arms are. A 'd' type represents galaxies that have luminous, fragmentary and loosely wound arms, and an 'm' type is for galaxies with no bulge and irregular appearance.

Lenticular galaxies

Lenticular (S0 type) galaxies do not have spiral arms but do have a bright central bulge of stars like the spiral galaxies. Unlike the spirals they do not have significant amounts of stars forming inside them.

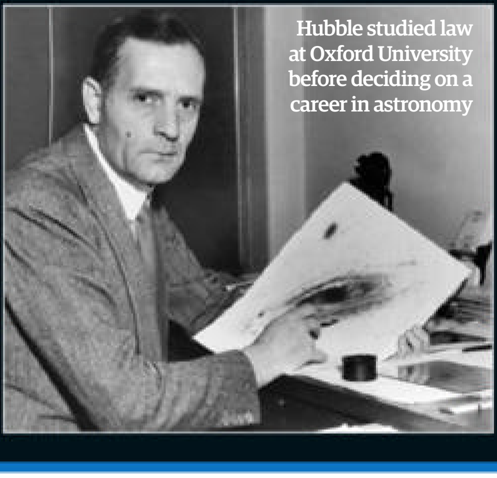
Irregular galaxies

Hubble identified a further group of irregular galaxies. He designated two types, the asymmetric Irr I that lacks a spiral or bulge structure that contains young stars, and Irr II, asymmetric galaxies that have no clearly visible stars or clusters.

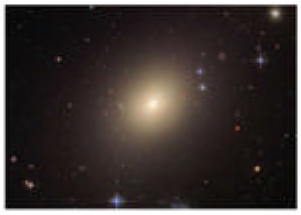
Classifying galaxies

Although lenticular and elliptical galaxies are often called 'early type' galaxies, and spirals look more perfectly formed, Hubble was at pains to point out that his scheme did not show the evolutionary path of galactic formation. Instead, the diagram should be used as a guide to the visual appearances of the galaxies as seen from Earth.

Hubble's system is not perfect because it depends on a subjective assessment of which category a galaxy fits into. Another problem is that it only deals with the galaxies as two-dimensional objects and does not fully represent their true three-dimensional structures. French astronomer Gérard de Vaucouleurs found several shortcomings with the scheme. In 1959, he extended it to include ring-like galactic structures and he gave numerical values to the different classes of galaxy. Certainly, advances in astronomy have provided more information about the structure of galaxies and more complex classification systems exist, but Hubble's system remains a useful guide to understanding their appearance and basic structures.

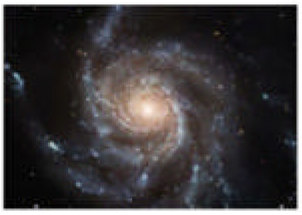

Hubble studied law at Oxford University before deciding on a career in astronomy

Galactic identity parade



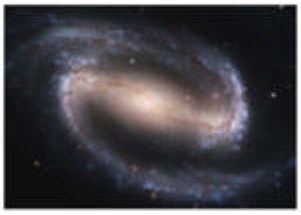
Abell S0740

The giant ESO 325-G004 E/S0 elliptical galaxy dominates the centre of the Abell S0740 galaxy cluster. The cluster is located in the Centaurus constellation at around 463 million light years from Earth.



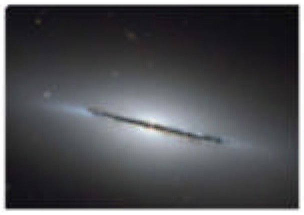
M101 – The Pinwheel Galaxy

M101 is only 21 million light years away in the Ursa Major constellation. It is the most prominent grand design Scd spiral galaxy in the sky and is 170,000 light years across.



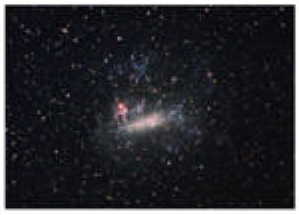
NGC 1300

This is an SBbc spiral barred galaxy with a diameter of around 110,000 million light years. It is at a distance of 61 million light years away and located in the southern constellation of Eridanus.



NGC 5866 – The Spindle Galaxy

This S0 lenticular galaxy is found in the Draco constellation. Only its 60,000 light year long edge is visible, from above it might reveal itself to be a spiral galaxy.



The Large Magellanic Cloud

Under Hubble's classification system, this irregular galaxy is on average 200,000 light years away. It is a satellite of our Milky Way galaxy and is full of glowing nebulas.

THE HUNT FOR EXOPLANETS

Meet the scientists who are hunting for worlds outside our Solar System in an attempt to find Earth-like planets that, like our own, could be hospitable to life

Written by Jonathan O'Callaghan

Up until 1992 the thought that there might be other sentient life out there in the universe was one that was generally met with incredulity and disbelief. Those branding aliens as real were looked upon disdainfully, and the mere suggestion that humans were just one of many types of life in the cosmos was not one that was given much credibility.

However, the discovery of an exoplanet (one outside our Solar System) orbiting the pulsar star PST B1257+12 in 1992 changed our entire preconception of the universe. If these planets could exist around such a volatile star, then surely they could also be found around more serene stars and especially those like our own Sun, where we already know the eight planets of our Solar System exist. And of course we also know one planet in our Solar System, Earth, is capable of supporting life. Extrapolating that ratio, there could be billions of Earth-like planets in our Milky Way alone.

The astronomers who found that first planet were Dr Dale Frail and Dr Aleksander Wolszczan. "We didn't begin by looking for planets," said Dr Frail. "We just found this unusual pulsar that was behaving in ways we didn't understand. It turned out to be the most robust planet discovery at the time. I remember very distinctly in 1992 that the planet-hunting community was thrilled about our pulsar planet discovery, because it really told them that they were on the right track, they just need to keep persisting. I think the field was struggling both financially and technically at the time, but the attitude after our discovery was that if planets can form around pulsars then they could form around anything. We gave a real boost to that community."

And so, the hunt was on. Where previously planet hunters had struggled to gain funding, the search for exoplanets shot to the top of agendas throughout the world. Agencies from NASA to Roscosmos to ESA began designing and developing planet-hunting telescopes, while private observatories began to devise techniques that would enable astronomers to search for planets around distant stars.

The initial favoured method that was used to find planets was the radial velocity technique, which observes perturbations in a distant star to indicate the presence of a planet. The current preferred way to find planets, however, is the transit method. To date thousands of planetary candidates that we know of have been found using the transit method, which we'll explain more about later.

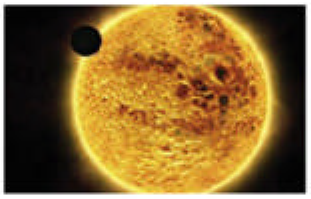
But while telescopes around the world trained their sights on potential planet-bearing stars, finding new worlds was proving rather difficult. Up until 2009 barely a hundred planets had been found and confirmed and, owing to the primitive methods available to find them, most of these were giant hot Jupiters with close orbits around their stars – worlds that would be inhospitable to life as we know it.

Finding large planets of this type is much easier because the methods used rely on an observational change in the host star, whether it's a gravitational wobble or a dip in its light as the planet passes in front of it relative to us. A large planet orbiting at high speed will produce frequent and noticeable effects on the star, whereas a smaller planet in a slower orbit further out is much harder to detect. To find smaller planets, and therefore ones that are more similar to Earth, astronomers needed a way to watch thousands of stars simultaneously rather than just focusing on a few at a time.

Fortunately, NASA had recognised the need for a wide-field observation telescope and had begun working on one at the beginning of the 21st Century. The telescope would be groundbreaking and do something never attempted before. It would be put into an orbit around the Sun, away from any interference, and it would train its sights on a specific area of the Milky Way galaxy. Known as the Kepler

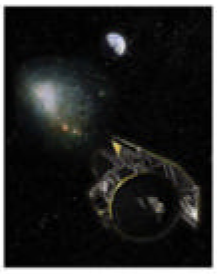
The Kepler telescope before it launched in 2009

Methods of finding exoplanets



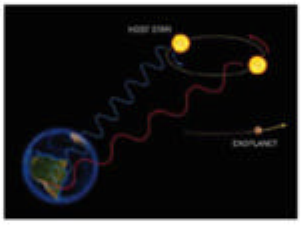
Transit method

As a planet passes in front of a distant star, it will cause a dip in the brightness of the star relative to us. Therefore, by measuring the brightness of many stars at once, we can detect the transits of planets as they pass in front of a star. This method is useful for finding a lot of planets, and it can also determine the mass and size of the planet as well as its orbital period. It is currently the favoured method of planet hunting, used by NASA's Kepler telescope among many others.



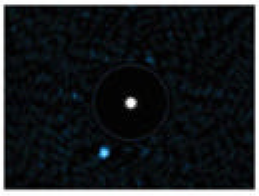
Microlensing

This method of finding planets relies on observing perturbations in a star caused by an exoplanet. To do this the star must be aligned with a background object, such as a galaxy or another star, and as the light from that background object passes around the planet, any exoplanets present will distort the incoming light and indicate their presence.



Radial velocity

By measuring the wobble of a distant star induced by the presence of a planet, just as our own Sun wobbles slightly due to planets such as the Earth, an exoplanet can be confirmed to exist. It's a tricky technique but it was favoured in the early days of planet hunting, although it has now been usurped by the transit method as the preferred method of finding planets.



Direct imaging

One of the most exciting methods of finding exoplanets is direct imaging. As its name suggests, direct imaging relies on telescopes taking actual pictures of planets around other stars. This is done by blocking the light of the star to find planets in orbit. Some direct imaging has already been done, and future telescopes will be expected to produce more and more images of distant worlds.

The team that started it all

Kepler space telescope

The Kepler team studies some of the many transiting planets they've found

To date, a huge majority of exoplanets we know of have been discovered by the Kepler space telescope team. Launched on 7 March 2009, Kepler sits in an Earth-trailing orbit around the Sun. Before its launch it was considered possible that planets in the universe were rare. Now, however, its thought that almost every star plays host to at least one planet.

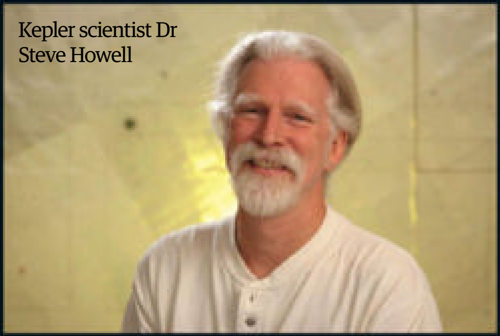
The telescope uses photometry to simultaneously observe thousands of stars. It watches for dips in the brightness of these stars as a planet passes in front, known as a transit, and measuring three of these transits confirms the planet's existence as well as its size owing to the amount the star dims. The orbital period can also be calculated from multiple planets, and ultimately its distance from its host star can be determined. Scientists have been poring over Kepler's data looking in earnest for the holy grail of planet hunting, a world similar in size to our own residing in the habitable zone of its star.

Of the hundreds of planets Kepler has found, though, it was the very first that elicited the most excitement. "The most exciting planet discovery was probably the very first one, when we actually looked at a light curve that came down very early on in the mission almost in real time and you could see the transit by eye," said Kepler project scientist Dr Steve Howell. "It was a planet that had been discovered before Kepler had launched so we knew it was there. It was a really big planet, and, boy, if we couldn't have found that we were in real trouble."

Aside from the early excitement that confirmed Kepler was in full working order, there have been a number of recent discoveries that have been just as interesting. "In the last few months we've found the planets Kepler-69 and Kepler-62 around stars kind of like the Sun," said Dr Howell. "They are planets that aren't much bigger than the Earth and these planets are in their star's habitable zone. They're probably rocky, or at least very water-rich planets. They are very exciting, they are really getting us towards the true Earth-analogue kind of planet."

At the time of writing a fault with one of Kepler's reaction wheels has left the telescope unable to do the precise positional movements needed to perform photometry and find new planets. However, the team are confident that even if the telescope can't continue hunting for planets, there is still plenty of data to be analysed and, even then, it leaves a lasting legacy that has led to the development of other planet-hunting telescopes.

"Kepler's been critically important," said Dr Howell. "I think that if Kepler had not been launched, other planet-hunting telescopes would have never even been thought about, and certainly wouldn't have been selected [for development]. The chances of these missions going ahead have increased because planets are such a hot topic these days."



Kepler scientist Dr Steve Howell

"Kepler-69 and Kepler-62 are in their star's habitable zone" **Dr Steve Howell**

Kepler in numbers

The telescope's facts and figures

132

Kepler has found 132 confirmed planets so far

17%

A planet 0.8-1.25 times the size of Earth is believed to reside around 17% of stars

50%

About half of the planets Kepler has found have been Neptune-sized

100k

Number of stars that Kepler has observed in hunt for planets

2,740

A further 2,740 planetary candidates are awaiting confirmation as fully fledged worlds

SuperWASP team member Dr Don Pollacco

Looking for strange new worlds

SuperWASP (Wide Angle Search for Planets)

While telescopes like Kepler cost hundreds of millions of dollars, planet hunting doesn't require a fortune to succeed. One such project is SuperWASP (Wide Angle Search for Planets), which at a cost of just half a million dollars has found over 100 planets outside our Solar System. SuperWASP has two robotic observatories, one on the island of La Palma in the Canary Islands and the other in South Africa. Each has eight lenses backed by high-quality CCDs to monitor stars and search for new worlds.

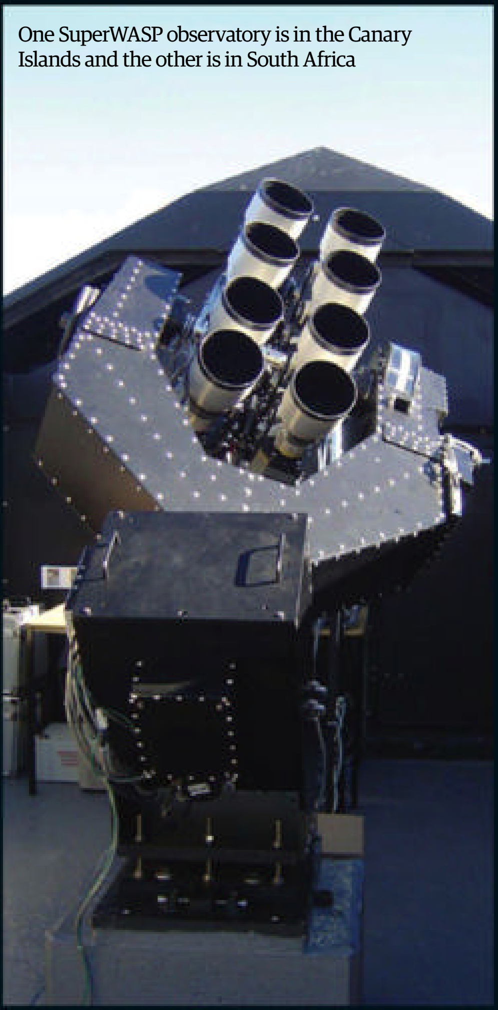
"We can't compete with [the programmes] that find small rocky planets, but we can find unusual things still," said SuperWASP team member Dr Don Pollacco. The two observatories have mostly been responsible for finding hot Jupiter-like planets, and SuperWASP can help to determine how abundant certain types of planets are in the universe.

One thing in particular that SuperWASP has helped to understand is how some of these planets got into very tight orbits around their star. "One thing SuperWASP has done over the years is that it has basically discovered that most of these planets that are close in have probably got there by interactions with other planets," explained Dr Pollacco. "If you look at something like Pluto, what you find is that Pluto is going in the opposite direction [to the rotation of the Sun]. What that tells you is that Pluto was never born where it is now, it's been somehow perturbed into that orbit."

Of SuperWASP's most notable discoveries, Dr Pollacco cites the exoplanet WASP-12b as one of his favourites. "WASP-12b is a really highly inflated planet, so it's got a mass of Jupiter but it's nearly twice Jupiter's size," he explained. "What that really tells you is there's some extra energy source going on in this planet that's inflating it, and there are a number of other planets like that, but we don't understand them."

Next up for Pollacco and the SuperWASP team will be to begin a new experiment called the Next Generation Transit Survey. "We're very close now to being able to detect planets with periods of maybe 100 or more days," explained Dr Pollacco. "They will potentially be two or three times the size of Earth and maybe ten Earth masses, so they're potentially rocky planets. And we're doing this all from the [surface of the Earth], you don't need to spend $600m [on a space telescope] to do it."

The SuperWASP observatories operate on a substantially lower budget than the likes of Kepler



One SuperWASP observatory is in the Canary Islands and the other is in South Africa

"You don't need to spend $600m to hunt for planets" **Dr Don Pollacco**

The WFIRST programme team, who recently received funding from NASA with a view to launching the WFIRST planet-hunting telescope in 2023

> “We’ll find thousands of exoplanets using the microlensing technique, and even some in the habitable zone” **Dr Neil Gehrels**

space telescope, NASA’s newest creation would prove to be the most important and useful planet-hunting telescope to date.

The Kepler telescope launched in 2009 to its predetermined position 150 million kilometres (93 million miles) from Earth in orbit around the Sun. It uses the aforementioned transit method to find new planets. To understand how it works, imagine you were staring at 20 light bulbs in a grid, and you knew some of these light bulbs had moths flying around them but you weren’t sure which. You observe the bulbs for a period of time and each time one of the bulbs dims you can presume that something has passed in front of it. By observing the dip in the light three times and measuring the time taken for the dips to occur, you can confirm that there is something flying around the bulb and you can work out the speed the object is moving at. With just this data alone, you can even measure the dip in brightness and, coupled with the knowledge of its orbital period and the size of the bulb, you can deduce the size of the object. From just these three calculations you know the speed of the moth, its size and its distance from the bulb.

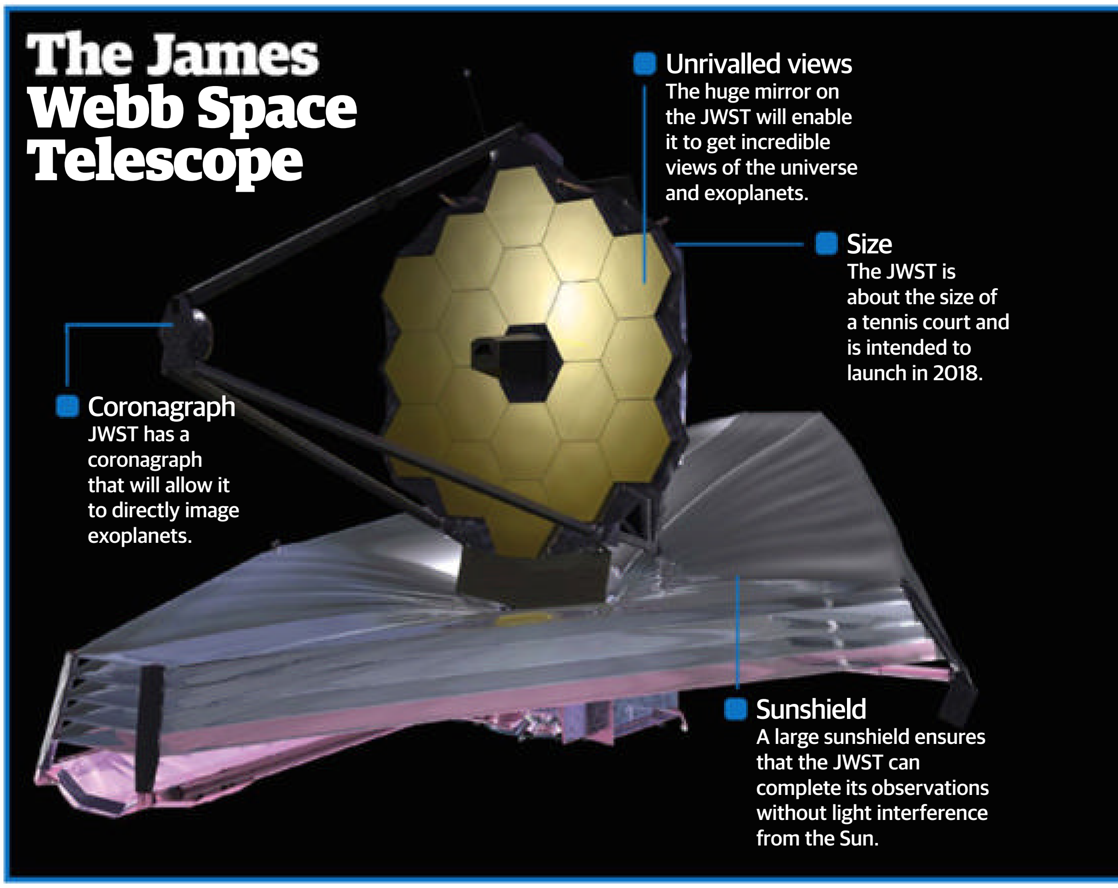
Kepler does this for 100,000 stars. So it observes all of them simultaneously, watching out for dips in their brightness, and then waits to confirm the regularity of the dips. By doing so it can deduce if there is a planet present around the star and then calculate its speed, size and distance from the star. At the time of writing, the Kepler space telescope is currently out of operation after losing functionality in one of the reaction wheels that allows it to accurately focus on these distant stars, but regardless, since it was launched it has provided scientists with a multitude of data to find new planets, much of which will take another two years to analyse. The field of planet hunting has been kick-started by Kepler with numerous projects now in operation around the world to find planets.

The detection of exoplanets has proved beyond reasonable doubt that almost every star in the universe plays host to a planet of some sort. However, as mentioned earlier the majority of planets we’ve found so far have been large Jupiter-sized worlds, many orbiting their stars in tight orbits and therefore having a scorchingly hot temperature. The holy grail of planet hunting is to find a world exactly like Earth, with the same size and mass in an orbit in its star’s habitable zone, where conditions are just right – not too hot and not too cold – and therefore water will be able to form. To date, no such world has been found.

However, in January 2013 astronomers at the Harvard-Smithsonian Center for Astrophysics reported that there were likely to be at least 17 billion Earth-sized worlds in our Milky Way galaxy alone. When you consider that there are hundreds of billions of galaxies in the universe, it is therefore highly unlikely that only one of these, our own Earth, is able to play host to life.

One of the difficulties in finding Earth-like worlds is the limiting factors of the methods we currently use to find planets. The transit method, for example, relies on multiple observations of the orbit of a planet around a star. Consider looking at our Sun from outside the Solar System; to definitively detect the Earth you would have to observe three transits of the Earth on the Sun, which would take three years. Therefore, only by observing stars for a long period of time can planets in habitable orbits be found. The Kepler telescope has so far completed over four years

The James Webb Space Telescope

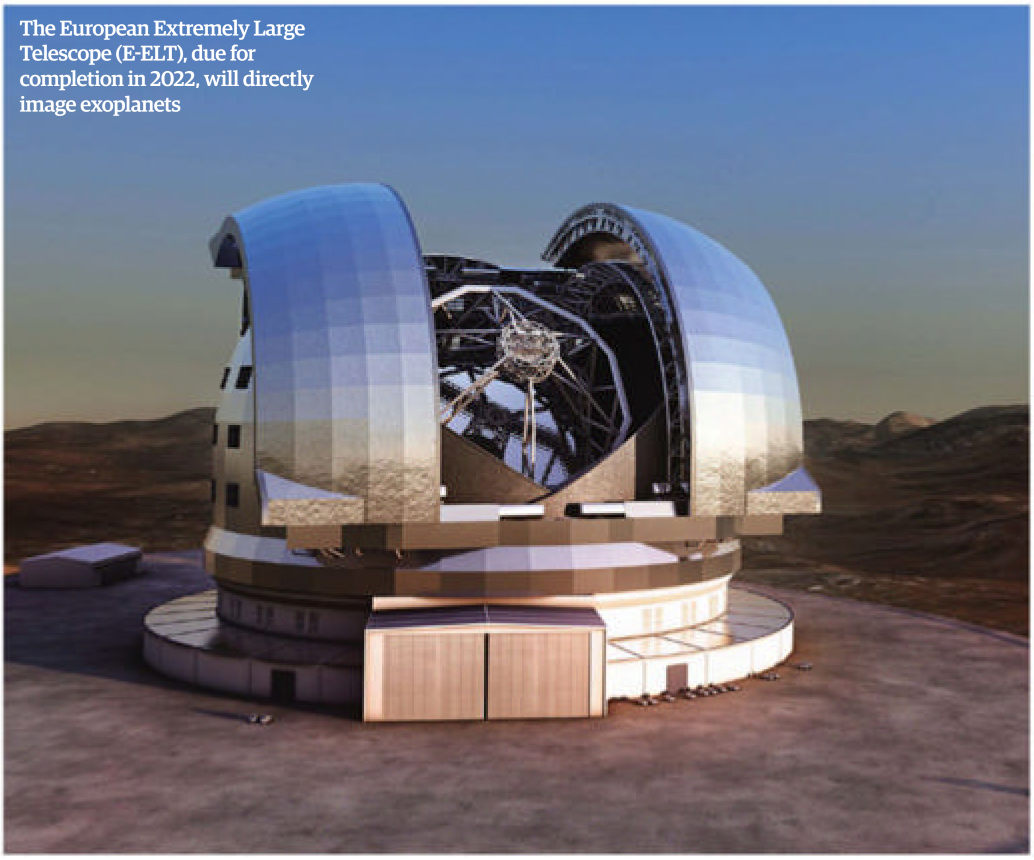


Unrivalled views
The huge mirror on the JWST will enable it to get incredible views of the universe and exoplanets.

Size
The JWST is about the size of a tennis court and is intended to launch in 2018.

Coronagraph
JWST has a coronagraph that will allow it to directly image exoplanets.

Sunshield
A large sunshield ensures that the JWST can complete its observations without light interference from the Sun.



The European Extremely Large Telescope (E-ELT), due for completion in 2022, will directly image exoplanets

of observations, so it is hoped that within its data may be hiding some of these Earth-like worlds. It's also thought that some habitable planets might reside in closer orbits around red dwarfs, which would mean their orbits are slightly faster and therefore detection might be easier

Perhaps, though, to increase our chances of finding a new Earth we need to change our methods of finding planets. One of the most promising techniques that has already been tested, and will be used more in future, is directly imaging exoplanets. Some modern observatories such as the European Southern Observatory's (ESO) Very Large Telescope (VLT) have already been able to take images of planets, and future telescopes like NASA's James Webb Space Telescope and the European Extremely Large Telescope will be able to continue this work.

To directly image a planet, the light of its host star must be blocked out using something called a coronagraph. This allows observations of the area around a star to be made, and any planets in orbit will be somewhat visible. Understandably, though, the method is incredibly difficult. "Smaller telescopes don't have a good enough angular resolution, so they don't have good enough imaging precision to really use a coronagraph," said Dr Neil Gehrels, one of the scientists on the WFIRST programme. WFIRST is a telescope that has recently received funding from NASA with a view to a launch in 2023. It will search for exoplanets using both the microlensing technique and possibly by directly imaging them.

"We'll find thousands of exoplanets using the microlensing technique, and even some that are in the habitable zone, similar to Earth-like planets," explained Dr Gehrels. "But then with the coronagraph, the really exciting thing we can do is to make a direct image of an exoplanet. We might

> "With the coronagraph, the really exciting thing we can do is to make a direct image of an exoplanet" **Dr Neil Gehrels**

Types of exoplanet

Rocky
Many of the smaller worlds found so far have been found in tight orbits around their star, meaning they are probably both hot and rocky with more of a resemblance to Venus than to Earth.

Earth-like
The holy grail of planet hunting is to find a world the size of Earth orbiting its star within the habitable zone. So far we haven't found one, but most scientists expect such a discovery to be made in the next few years.

Super-Earth
Planets found in habitable zones so far have tended to be much larger in both size and mass than the Earth. This has led scientists to postulate that these giant worlds could bear water and possibly even life.

Hot Jupiter
The majority of planets found to date are hot Jupiters, giant gas planets orbiting very close to their host star. In recent years larger planets have also been found orbiting further away from their star.

Imaging exoplanets

The James Webb Space Telescope

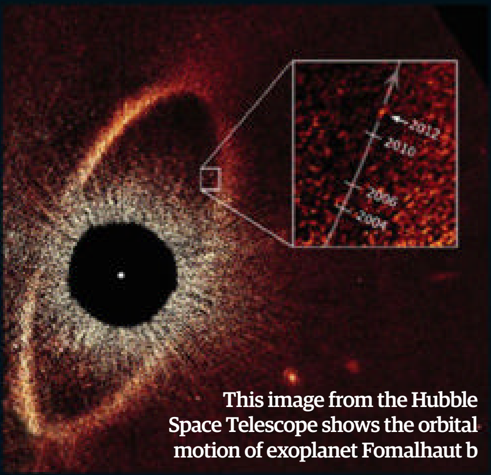
The most exciting area of planet hunting currently being developed is undoubtedly that of direct imaging. To directly image exoplanets, something known as a coronagraph is used, an instrument present on several telescopes including NASA's Hubble Space Telescope. This blocks the light of the host star, allowing the scope to see around the star and possibly detect a planet. On the right of this page you can see an incredible composite image of a dust disc around the Fomalhaut star taken by Hubble, and within this disc a planet called Fomalhaut b was discovered on a 2,000-year orbit around the star.

"We knew there was a ring [around Fomalhaut] but we didn't really have very high hopes of being able to see it, so we were kind of surprised when we actually found this very nice ring," said Dr Mark Clampin, one of the discoverers of Fomalhaut b and a project scientist working on the JWST. "When we were going through our data we found there was a point source there [indicating a planet] that we were not expecting to find. So we started to study this planet around Fomalhaut and not the ring."

One of the difficulties, however, is that planets tend to be very dark. Their host star must be sufficiently bright to enable the planet to be seen as it reflects more light, or the planet needs to have characteristics that make it more visible. "The reason we could image [Fomalhaut b] is because it's a lot brighter than it should be," continued Dr Clampin. "It looks like the planet has a big ring of dust around it like Saturn, and that dust is boosting the light of the planet so it appears brighter."

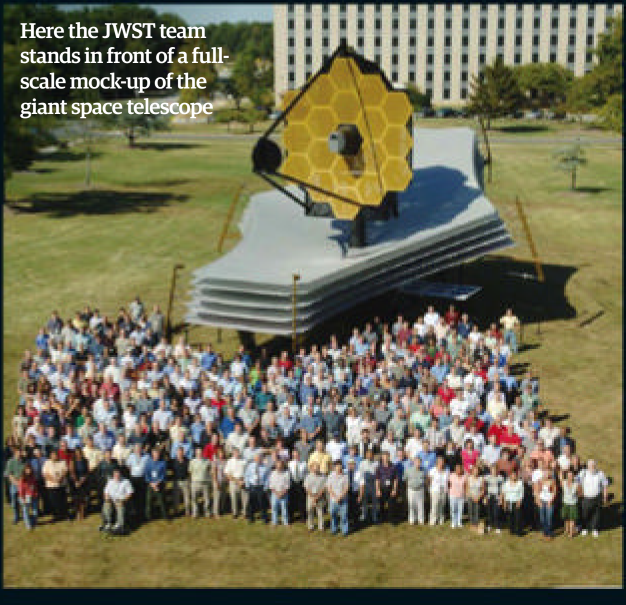
The launch of JWST, though, will provide the biggest boost for planet imaging. "JWST consumes my every waking hour at the moment," said Dr Clampin. "I'm really looking forward to JWST because I think, while it won't be able to directly image rocky planets, it will do a really fantastic job of studying planets around younger stars. And using different techniques like transit spectroscopy [studying a planet as it passes in front of its host star] we will be able to make observations of planetary atmospheres around super-Earths."

> "We will be able to observe planetary atmospheres around super-Earth" **Dr Mark Clampin**



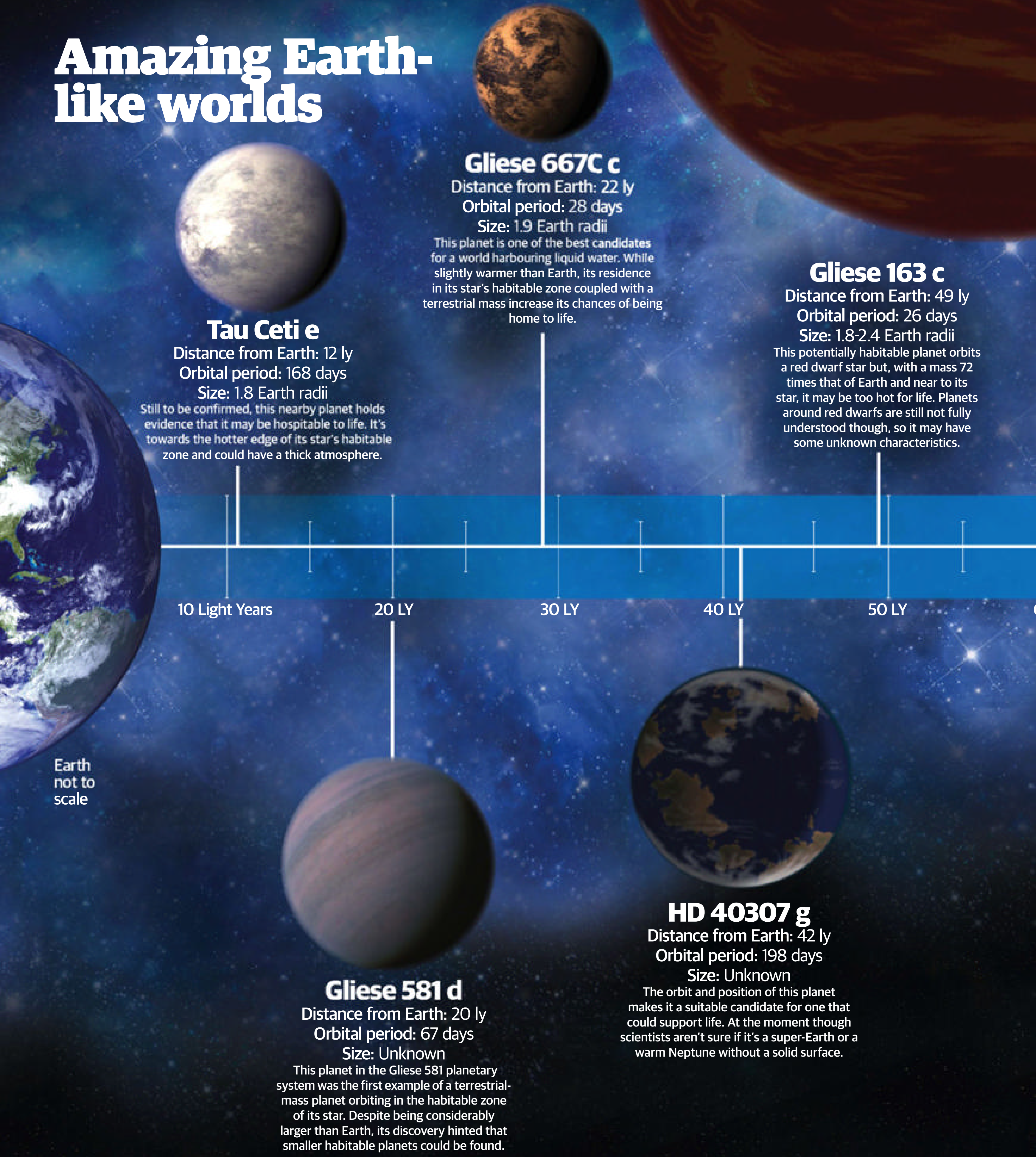
This image from the Hubble Space Telescope shows the orbital motion of exoplanet Fomalhaut b

Dr Mark Clampin is project scientist on the James Webb Space Telescope and currently works on imaging exoplanets



Here the JWST team stands in front of a full-scale mock-up of the giant space telescope

Amazing Earth-like worlds



Tau Ceti e

Distance from Earth: 12 ly
Orbital period: 168 days
Size: 1.8 Earth radii

Still to be confirmed, this nearby planet holds evidence that it may be hospitable to life. It's towards the hotter edge of its star's habitable zone and could have a thick atmosphere.

Gliese 667C c

Distance from Earth: 22 ly
Orbital period: 28 days
Size: 1.9 Earth radii

This planet is one of the best candidates for a world harbouring liquid water. While slightly warmer than Earth, its residence in its star's habitable zone coupled with a terrestrial mass increase its chances of being home to life.

Gliese 163 c

Distance from Earth: 49 ly
Orbital period: 26 days
Size: 1.8-2.4 Earth radii

This potentially habitable planet orbits a red dwarf star but, with a mass 72 times that of Earth and near to its star, it may be too hot for life. Planets around red dwarfs are still not fully understood though, so it may have some unknown characteristics.

Gliese 581 d

Distance from Earth: 20 ly
Orbital period: 67 days
Size: Unknown

This planet in the Gliese 581 planetary system was the first example of a terrestrial-mass planet orbiting in the habitable zone of its star. Despite being considerably larger than Earth, its discovery hinted that smaller habitable planets could be found.

HD 40307 g

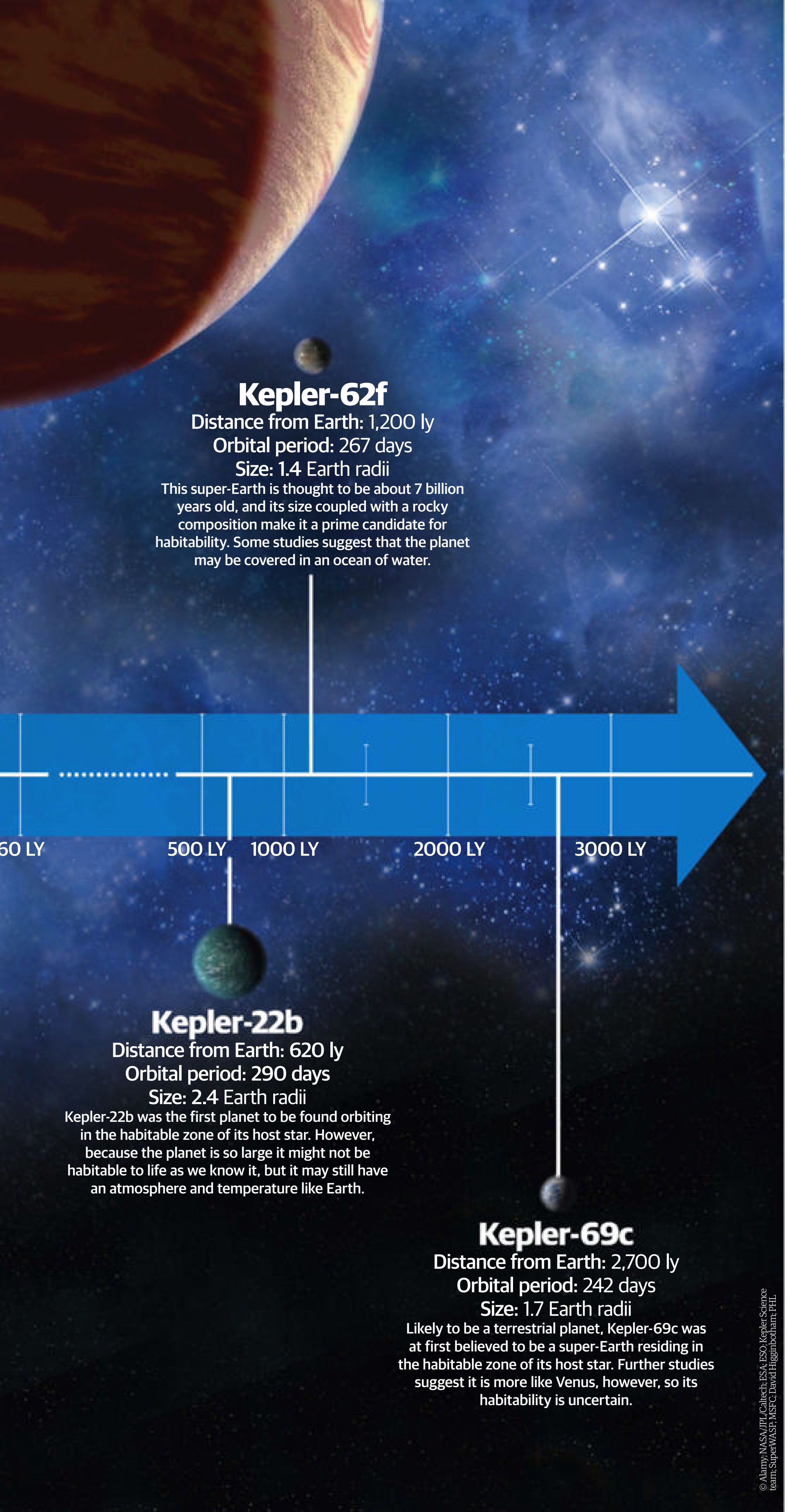
Distance from Earth: 42 ly
Orbital period: 198 days
Size: Unknown

The orbit and position of this planet makes it a suitable candidate for one that could support life. At the moment though scientists aren't sure if it's a super-Earth or a warm Neptune without a solid surface.

be able to get close in to Earth-mass worlds. The telescope has spectroscopy on board, so we could look at the constituents in the atmosphere."

As Dr Gehrels mentions, studying the atmospheres of exoplanets is another area of planet hunting that has garnered a lot of interest recently. By analysing the light of a star as it passes through a planet and studying the changes in its spectroscopy, scientists are able to determine what sort of atmosphere the planet might have. Some telescopes like the aforementioned James Webb Space Telescope may even be able to make direct analysis of alien atmospheres, finding out if they bear any similarity to ours on Earth and, ultimately, possibly indicating that the planet is habitable.

Every month we seem to hear of an exciting new exoplanet discovery, and as more and more telescopes come online we will continue to find amazing new worlds that are not only similar to Earth but are in fact so dissimilar that they question our current theories of planet structure and formation. Thanks to telescopes like Kepler scientists have a great starting point to search for planets. They already know of thousands of stars with planets in our Milky Way, and as our methods of detection and analysis improve we will move closer and closer to finding a world like our own. ■



Kepler-62f

Distance from Earth: 1,200 ly

Orbital period: 267 days

Size: 1.4 Earth radii

This super-Earth is thought to be about 7 billion years old, and its size coupled with a rocky composition make it a prime candidate for habitability. Some studies suggest that the planet may be covered in an ocean of water.

Kepler-22b

Distance from Earth: 620 ly

Orbital period: 290 days

Size: 2.4 Earth radii

Kepler-22b was the first planet to be found orbiting in the habitable zone of its host star. However, because the planet is so large it might not be habitable to life as we know it, but it may still have an atmosphere and temperature like Earth.

Kepler-69c

Distance from Earth: 2,700 ly

Orbital period: 242 days

Size: 1.7 Earth radii

Likely to be a terrestrial planet, Kepler-69c was at first believed to be a super-Earth residing in the habitable zone of its host star. Further studies suggest it is more like Venus, however, so its habitability is uncertain.

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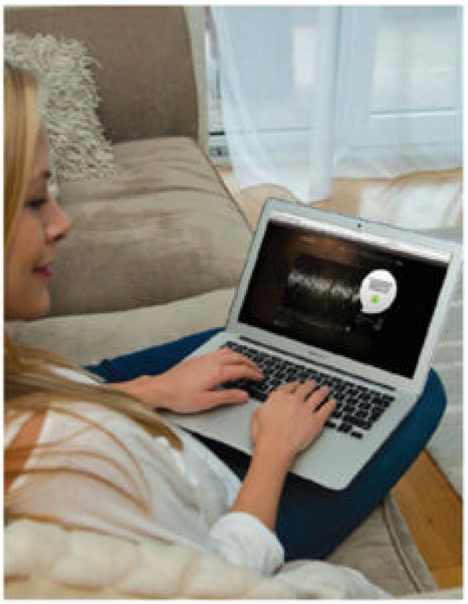

How you can become a planet hunter

Planet hunting isn't just for professional scientists and astronomers. If you want to start searching there are a number of projects on the internet that you can get involved with to help sift through data to find planets. One such project is found online at planethunters.org, where you can view graphs of the light emitted from distant stars to find planets using the transit method. Who knows, perhaps you could help find the first true Earth-like world?

5 AMAZING FACTS ABOUT

The Apollo spacecraft

The Apollo programme cost $200 billion

The initial estimated cost of the Apollo programme was around $7 billion (£4.6 billion), before it was revised to $20 billion (£13.2 billion) by the first NASA administrator, James Webb. By the end of the programme, the 17 missions had cost the US government $23.9 billion (£15.8 billion), around $200 billion (£132 billion) in today's money.

Apollo 1 met a tragic end

The first manned Apollo mission was scheduled to launch on 21 February 1967 but never made it. During a launch pad test on 27 January, a cabin fire broke out destroying the Command Module and killing all three of its crew: Virgil 'Gus' Grissom, Edward White and Roger Chaffee. The widows requested that the test flight be renamed as the first Apollo mission and NASA formally retired the Apollo 1 name.

Apollo's power could light a city

The energy generated by the Apollo spacecraft's re-entry into the atmosphere was incredible. It was equivalent to around 86,000 kilowatt-hours of electricity, which is enough to illuminate all of Los Angeles' street lights for 104 seconds or to briefly lift all the people in the United States nearly 30 centimetres (one foot) off the ground.

Apollo used 3 million litres of fuel

The Apollo lunar programme's Saturn V launch vehicle used a total of around 5.6 million pounds of propellant (or 960,000 gallons) to land on the Moon. With a fuel efficiency of around 15 miles per gallon, you could drive for nearly 30 million kilometres (18.6 million miles) or 400 times around the Earth. That much fuel aboard the Saturn V increased its weight by 2.55 million kilograms (5.6 million pounds).

NASA erased the Apollo 11 video footage

Unbelievably, the video recording of the original Apollo 11 Moon landing was erased in subsequent years. NASA had a shortage of magnetic tape in the years following the famous 1969 mission and simply recorded over it, kicking themselves 40 years later on the anniversary of the landing, when it wanted to digitally restore the original analogue recording.

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Own Your Own Piece of Space Shuttle History

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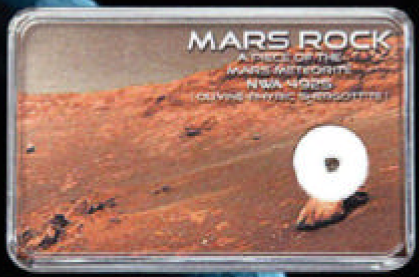

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The Last Space Shuttle Commander

Christopher J Ferguson reveals his regret at the retirement of NASA's iconic Space Shuttle in 2011, but tells us how he's now looking forward to working on the next generation of spacecraft at Boeing

Interviewed by Jonathan O'Callaghan

INTERVIEWBIO

Christopher J Ferguson

Age: 51
First mission: STS-115
No. of missions: 3
Time in space: 40 days

Born on 1 September 1961, Ferguson is a retired US Navy Captain and NASA astronaut. He was the pilot on STS-115 in September 2006 and commander for STS-126 in November 2008, before serving as the final Space Shuttle commander aboard Atlantis for the STS-135 mission in July 2011. He now works at Boeing, helping the company build a new generation of space vehicle with its CST-100 capsule under contract from NASA.

Why did you decide to become an astronaut?
I've always had this fascination with things I didn't completely understand. I spent a lot of time in the Navy only because I could never really understand how an aircraft carrier worked – I thought it was just one of the most intriguing places on Earth. So I was in the Navy for a good 15 years and then the next logical step, the next thing I really couldn't understand, was what it's like to operate in space. As I matured in my Navy career I realised I had been through most of the steps the early astronauts had done, and I thought I'd give it a go. I started applying as early as 1991 and I endured a couple of rejections, but as with most good things in life persistence certainly pays off and I finally got picked to join NASA in 1998.

Was it an exciting time to be involved in NASA's space programme?
What a ride it was. It was kind of the heyday of the Space Shuttle programme. The ISS [International Space Station] was just coming online and we knew that we had an incredible amount of Space Shuttle flights, 35 in total, dedicated to the space station's construction. I don't think the public could truly appreciate the magnitude of the effort, but when you think there were 35 Space Shuttle missions, each of them carrying about 50,000 pounds [22,500 kilograms] of cargo into space, and not to mention the many Soyuz flights, Progress cargo flights and Proton flights with the Russian segments, it was truly a global construction effort and I look back at my time and think I was just so lucky to be a part of the whole thing.

How did it feel to be selected for your first flight as the pilot on STS-115 in September 2006?
There are few things in life that are comparable to getting selected to go on a spaceflight. I was just thrilled. Of course our training for that flight was delayed for over two and a half years because of what happened with Columbia [in February 2003], but like anything good it's worth waiting for in life. I flew in pretty quick succession, 2006, 2008 and then in 2011, so I was very, very fortunate. It's one of those moments in life you'll never forget, getting picked and realising 'boy, you know, you're really going to do this'. So it was a great joy.

What was it like on your first flight?
I really didn't know what to expect. You hang around the office long enough and you begin to hear everybody's stories about what their experiences were like, but while you can simulate most things [on the ground] you can never simulate what it's like to be in zero-g. I remember a moment probably two or three minutes after launch when I looked out the window off to my right and saw the east coast of the United States just kind of disappear beneath us. And I looked outside, then inside, and outside again and I thought, you know, this is amazing. We are flying into space. From that moment I was very aware how magnificent this was. Here I am in a spaceship that looks an awful lot like an aeroplane and we are literally flying this thing into space.

Having been a test pilot, how did it feel to pilot the Space Shuttle?
You're so prepared, especially for what we call the dynamic phases of flight, ascent and re-entry, but between all that it's completely different. It's a different world. You fly backwards, you fly upside down, and after a while you forget you're even in an aeroplane because it doesn't behave like one in orbit. You usually are upside down and backwards going tail first looking at the Earth, and what a

> "There are few things in life that are comparable to getting selected to go on a spaceflight"

Christopher Ferguson was the commander on STS-135, the last flight of NASA's iconic Space Shuttle that was in operation from April 1981 to July 2011

Ferguson on the ISS, where Space Shuttle Atlantis spent over eight days docked in July 2011

surreal experience that is. I can recall a moment we actually flew over a couple of hurricanes that were in the Atlantic Ocean and to be able to look out the overhead windows straight into the eye of a hurricane is one of those 'pinch me' moments in space, when you can't believe you're actually doing what you're doing.

What was it like to be chosen as the commander for the final Space Shuttle flight, STS-135?

It was sort of a mixed blessing for me. I knew that my name was up in the rotation [for the last mission] but it was a flight that might not happen, it was kind of like being a part of Apollo 18 [laughs]. Then the Space Act of 2010 kind of baselined the Congressional funding for this additional flight [so it went ahead]. But what I realised not too far into training was that I was not just a crewmember on a Space Shuttle flight, but it was sort of my job to say goodbye to everybody, folks that had worked an entire career on this vehicle. They knew they were going to head into retirement at best and perhaps at worst they were going to lose their job in the middle of their career. So it became a very delicate balancing act to kind of sing the praises of the Shuttle programme as a whole, and at the same time respect and acknowledge the people who were soon going to lose their jobs who had been a part of it for so many decades.

Do you think it was the right decision to retire the Space Shuttle?

If you had asked me back in 2003, which is when the decision was made to retire the Space Shuttle, I would have said of course this is right after losing Columbia. Losing two out of the five Space Shuttles is not great odds, and if we continued to fly this thing for another 20 years, chances were we were going to lose another one. So at the time I would have said, knowing that something else [the Constellation programme] was on the horizon, it's probably not a bad idea for us to move on. But as the days got closer and then the Obama administration cancelled the Constellation programme [in 2010] we realised there was going to be a substantial gap between the Space Shuttle and whatever followed it. At those moments I gave pause and regretted feeling the way I did back in 2003 - that it was a good idea to shut the Space Shuttle programme down. I think looking at all the events that had transpired between 2003 and 2010 the wise thing would have been to preserve America's access to low-Earth orbit [LEO] and to continue flying the Space Shuttle until we had clear direction and an approved plan by Congress to get back to LEO at a defined date. We're in that gap now, which is what I'm a part of with Boeing, but after realising the impact of it I would have said we should keep flying it perhaps just twice a year to know that we can get [to LEO] and we're not reliant exclusively on the Russians.

> "To build a spacecraft is not just a once-in-a-lifetime opportunity, it's a once-in-a-multi-generation opportunity"

Were you proud to be chosen as the last commander of the Space Shuttle?

Yeah, absolutely, but again it was sort of bittersweet putting the Shuttle programme to bed. In four years when we [Boeing] are ready to fly I'm going to look back and think we've spent a long time to get back to something that we used to do at will for three decades in the Shuttle programme.

What was the most notable moment from that final flight?

One in particular was the night before re-entry. The last flight control team had come into the flight control centre and I had the opportunity to expound a little bit on my thoughts with them, and tell them all to just enjoy the moment and to thank them profusely on behalf of all the astronauts for what they have done throughout the years. Those one-on-one discussions with the flight control teams as they left was probably the most noteworthy memory from that last flight.

Following the retirement of the Shuttle, why did you decide to join Boeing?

I'd been talking to Boeing a little bit on and off before the flight, and then afterwards I knew that

Boeing was one of the potential providers for what we call [NASA's] Commercial Crew service along with SpaceX and Sierra Nevada Corporation. And I knew Sierra Nevada had their astronaut, SpaceX had theirs, but Boeing didn't have one. When I say 'their astronaut', it's just nice to have somebody on board helping guide the development of the interior of the spacecraft from a crew's perspective and to make sure it satisfies the intent of the mission. We have a lot of experience, 50 years of flying in space, and the astronauts really are the ones who know how well a craft operates in space. I knew I didn't want to spend six months on the space station [as an ISS astronaut] as the training templates for the ISS missions are very rigorous and long and I kind of thought it was time for me to turn that over to some of the younger astronauts, so here was an opportunity to join a company who was potentially working on the next craft [the CST-100 capsule] that will launch from American soil and take astronauts up, and I thought how can I possibly turn something like this down. And I haven't looked back, it's been a joy ever since I got to Boeing about a year and a half ago.

Is it exciting to be working on the next generation of space vehicles with Boeing's CST-100 capsule?
Yeah, and I tell everybody working with me and for me that to build a spacecraft is not just a once-in-a-lifetime opportunity, it's a once-in-a-multi-generation opportunity. I mean the last time we did this was in the mid-Seventies as we were designing the Space Shuttle, and a lot of the people associated with that work have retired or are no longer with us, and that was a long time ago. So a lot of this we're having to re-learn, but I'm amazed at the depth and breadth that Boeing has and their ability to resurrect this latent talent that it had within, because you know Boeing's been involved in just about every human spacecraft since the Mercury days. I look at this team I'm working with and I'm humbled in their presence because I thought I knew it all, but in reality I knew very little. I'm very proud in our effort and I look forward to seeing us back in orbit again very soon.

Would you like to fly on the CST-100?
You know I would love to, but I get back to my original comment of this being a business for the younger astronauts. But if Boeing asks me to do it I'll have to have a very long conversation with my lovely wife and ask her if she's ready to actually go through with something like this again. It's hard to let go, the question is will I be able to or not. That day is still a way off, we're not scheduled to fly a human spaceflight until the end of 2016, so there's a lot of open ocean between now and that date. But if they ask me I'll seriously consider it, let's leave it that way.

What are you guys working on at the moment?
Well now we're working on finding our landing sites. We're planning on the craft coming down on land, so we'll come down under parachutes to a landing site. Finding that perfect landing site in the US, even though the US is a big country, is difficult because there are just so many constraints that drive you to just a few select areas. We want a large enough area about eight kilometres (five miles) in diameter to provide for wind variations and de-orbit entry variations, so we want to give ourselves a real big target, and finding a big target like that even in the desolate areas of the western US is not exactly easy to do. So we're looking for up to four different landing sites to give us many opportunities to return. We are also actively developing our mock-up. The interior geometry of the spacecraft has largely been defined and the exterior geometry has been defined, so we're just now in the stages of making a mock-up to make sure that it works and that the crew has enough room to manoeuvre and function within this very limited environment, which is much smaller than the Space Shuttle. And also the aerodynamics team are working very hard on ascent aerodynamics, and that's done in collaboration with the United Launch Alliance [ULA], who's the provider of the Atlas V launch vehicle [that the CST-100 will use].

Is Boeing co-operating with its competitors, Sierra Nevada Corporation and SpaceX?
No, I would have to say it's an all-out competition. I do maintain some back channel communication with my fellow former [NASA] colleagues at those two companies, but just to the extent that we make sure we understand NASA's requirements. As far as the design is concerned everything is considered proprietary. We want to make sure we keep our design and the way we intend to do business as under wraps as possible. We [Boeing] have got a lot of experience doing this and we like that advantage. We think that we have a solid lead in terms of human space travel.

Is the privatisation of spaceflight important for the future of space travel?
I think about it in terms of what the possibilities are. I sort of envision a Boeing, or Sierra Nevada or SpaceX, astronaut heading to their vehicle outfitted in Boeing regalia. Now you've got really the first vestiges of a commercial space line where anybody with a lot of money, at least in the early stages of the programme, could do something like this. Air travel was the same way initially back in the Twenties when it started to take-off – only the wealthy did it. Rocket travel to LEO will be just the same way initially, but the more you do it the more confidence that the public has in your ability to do it safely and the more customers you fly you begin to get into economies of scale and suddenly it's within the grasp of people who would never have been able to consider something like this even ten years ago. So from that perspective I think it's very exciting. A commercial pilot taking a commercial paying crew into space is just kind of mind-boggling if you think about it, but I can see in ten years it being a distinct reality.

Commander Chris Ferguson and pilot Doug Hurley on the Space Shuttle's flight deck during STS-135

Ferguson now works for Boeing, who is planning a manned launch of its new CST-100 capsule in late 2016

The final voyage of Space Shuttle Atlantis in July 2011, marked the end of the Shuttle era

© NASA; BLM Nevada/Boeing

Messier 106

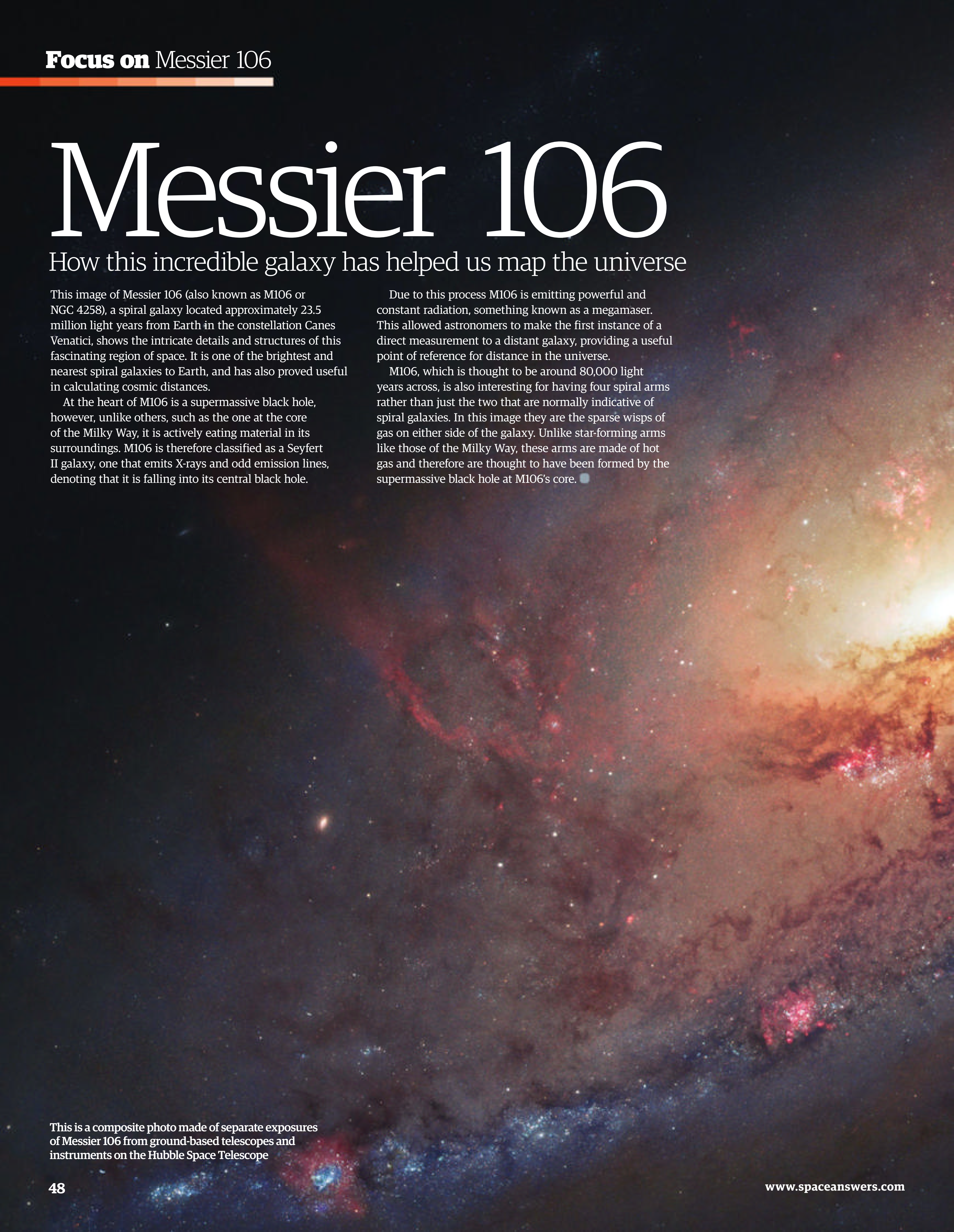
How this incredible galaxy has helped us map the universe

This image of Messier 106 (also known as M106 or NGC 4258), a spiral galaxy located approximately 23.5 million light years from Earth in the constellation Canes Venatici, shows the intricate details and structures of this fascinating region of space. It is one of the brightest and nearest spiral galaxies to Earth, and has also proved useful in calculating cosmic distances.

At the heart of M106 is a supermassive black hole, however, unlike others, such as the one at the core of the Milky Way, it is actively eating material in its surroundings. M106 is therefore classified as a Seyfert II galaxy, one that emits X-rays and odd emission lines, denoting that it is falling into its central black hole.

Due to this process M106 is emitting powerful and constant radiation, something known as a megamaser. This allowed astronomers to make the first instance of a direct measurement to a distant galaxy, providing a useful point of reference for distance in the universe.

M106, which is thought to be around 80,000 light years across, is also interesting for having four spiral arms rather than just the two that are normally indicative of spiral galaxies. In this image they are the sparse wisps of gas on either side of the galaxy. Unlike star-forming arms like those of the Milky Way, these arms are made of hot gas and therefore are thought to have been formed by the supermassive black hole at M106's core.



This is a composite photo made of separate exposures of Messier 106 from ground-based telescopes and instruments on the Hubble Space Telescope

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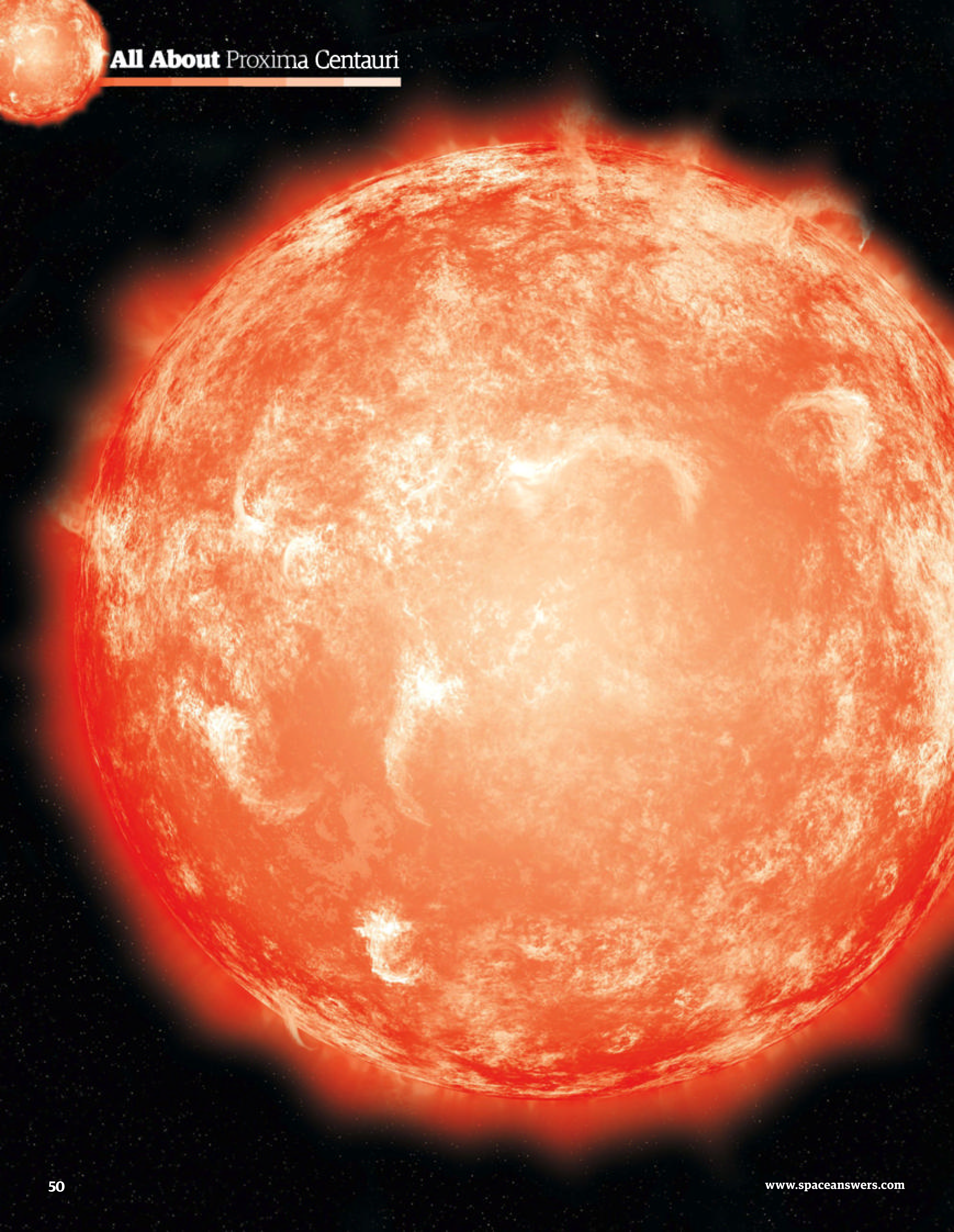
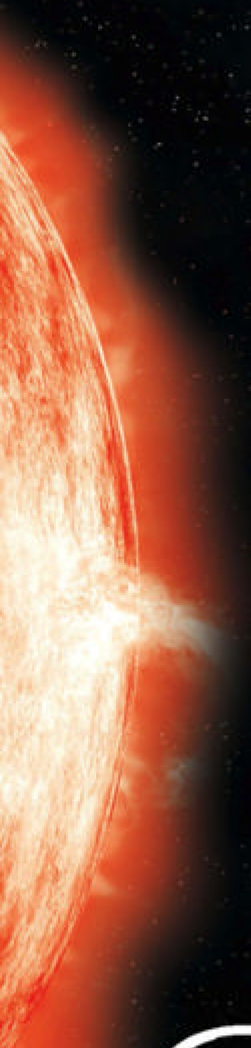




All About...

PROXIMA CENTAURI

Written by Shanna Freeman

This tiny star has captured our interest in a big way as it's the closest one to Earth after our own Sun

Red dwarfs are the most common type of star in our galaxy, but they're impossible to observe from the Earth with the naked eye because they're the dimmest stars. They're also very small and relatively cool due to their low mass. The red dwarf Proxima Centauri is among the smallest and dimmest, but it has the special significance of being the closest star to us other than the Sun.

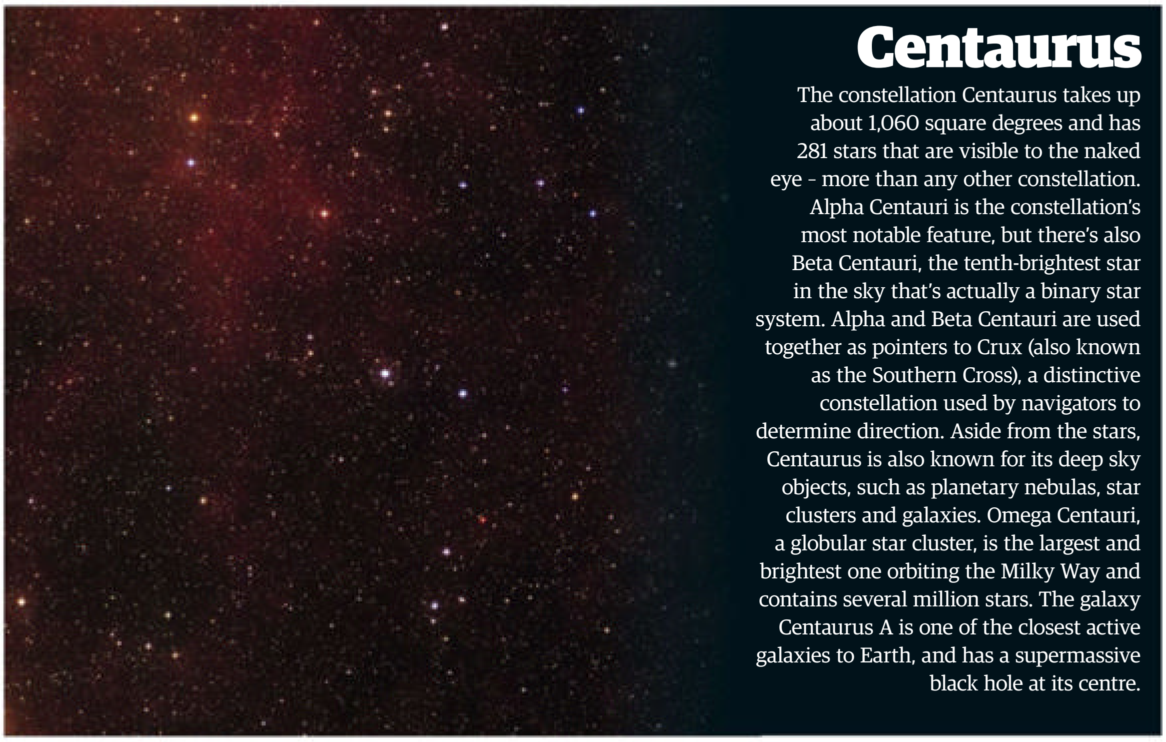
Proxima Centauri is approximately 4.24 light years (268,000 AU) away, located in the Centaurus constellation. The star is estimated to remain the closest star to ours for another 30,000 years or so, at which point the star Ross 248 in the Andromeda constellation will come closer (it's currently about 10.3 light years away).

Proxima Centauri is located about 15,000 AU from the next-closest star, the binary system Alpha Centauri. This relative closeness is how Proxima came to be discovered. In 1915, Scottish-South African astronomer Robert Innes observed a star that had the same proper motion - the apparent change of a star's position on the celestial sphere - as Alpha Centauri, which had been first observed in 1689. Depending on who you ask, Proxima is either a companion to Alpha Centauri or a third star in the system.

Since its discovery, Proxima has been closely observed. Because it's a red dwarf, it will be around for much longer than our Sun - at least four trillion more years - thanks to its slow consumption of fuel. And unlike the Sun, Proxima will completely use up its hydrogen during the fusion process. Satellite X-ray telescopes have provided crucial information about its activities. The Einstein Observatory, an X-ray telescope that orbited the Earth from 1978 to 1982, took the first X-ray images of the star and recorded a solar flare - flashes of brightness and heat caused by magnetic activity. This confirmed astronomer Howard Shapley's announcement in 1951 that Proxima Centauri was a flare star. The European Space Agency's European X-ray Observatory Satellite (EXOSAT), German ROSAT, and the Japan Aerospace Exploration Agency's Advanced Satellite for Cosmology and Astrophysics (ASCA) have all observed numerous solar flares on Proxima.

Land-based telescopes have also given us data about Proxima. Operated by the European Southern Observatory, the Very Large Telescope (VLT) helped to determine Proxima's distance and size. The star has a mass about one-eighth that of the Sun's, but it's about 40 times denser. Proxima's corona, or plasma 'atmosphere' extending into space beyond the surface, can actually be hotter than that of the Sun - 3.5 million Kelvin as opposed to 2 million Kelvin. On average, its overall temperature is about 3,000 Kelvin. Observations of Proxima's chromosphere indicate that it has a rotation period of about 31 days.

Although the closeness of Proxima Centauri has made for plenty of observation, there are* still some burning questions. Are there any planets orbiting the star? And if so, are they habitable? The Hubble Space Telescope hinted at the possibility of a planet near Proxima Centauri during observations in 1998, but no further evidence has appeared upon subsequent imaging. Proxima was to have been a target of the Space Interferometry Mission (SIM), a NASA space telescope mission that ultimately got cancelled. The star's closeness continues to make it a promising destination for both observation and actual interstellar travel, and eventually we'll get a better look at our neighbouring star. ■

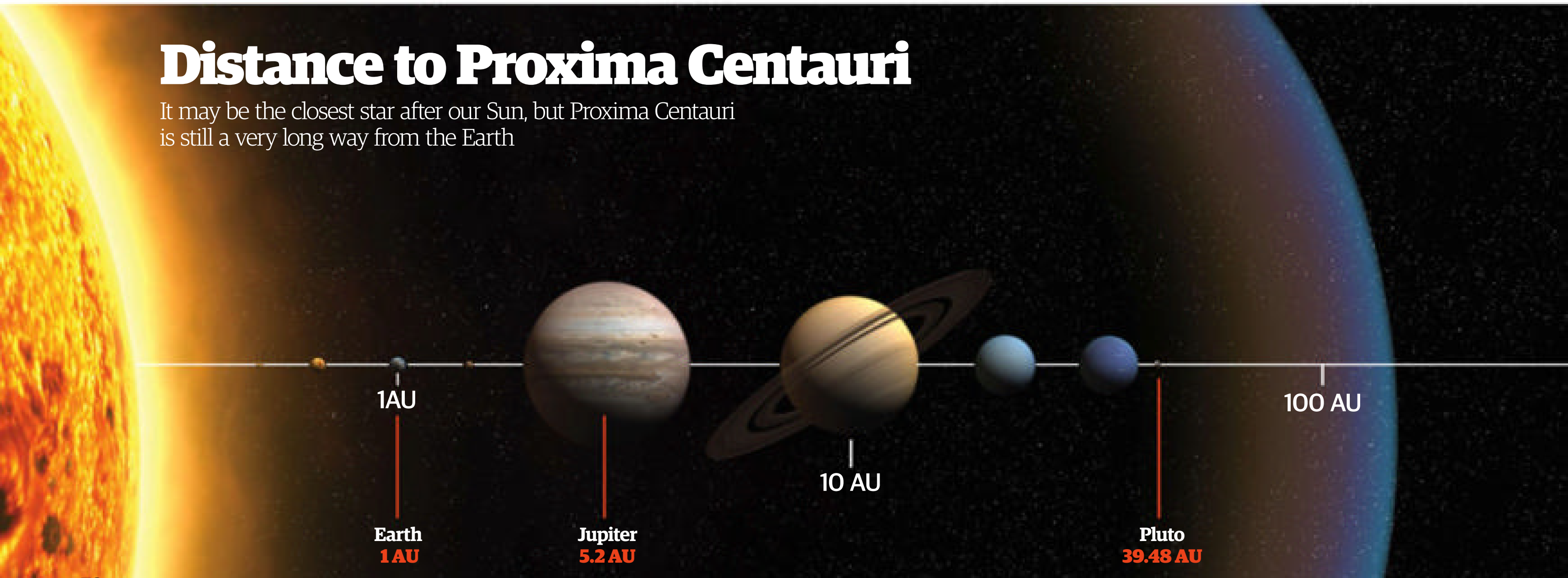


Centaurus

The constellation Centaurus takes up about 1,060 square degrees and has 281 stars that are visible to the naked eye - more than any other constellation. Alpha Centauri is the constellation's most notable feature, but there's also Beta Centauri, the tenth-brightest star in the sky that's actually a binary star system. Alpha and Beta Centauri are used together as pointers to Crux (also known as the Southern Cross), a distinctive constellation used by navigators to determine direction. Aside from the stars, Centaurus is also known for its deep sky objects, such as planetary nebulas, star clusters and galaxies. Omega Centauri, a globular star cluster, is the largest and brightest one orbiting the Milky Way and contains several million stars. The galaxy Centaurus A is one of the closest active galaxies to Earth, and has a supermassive black hole at its centre.

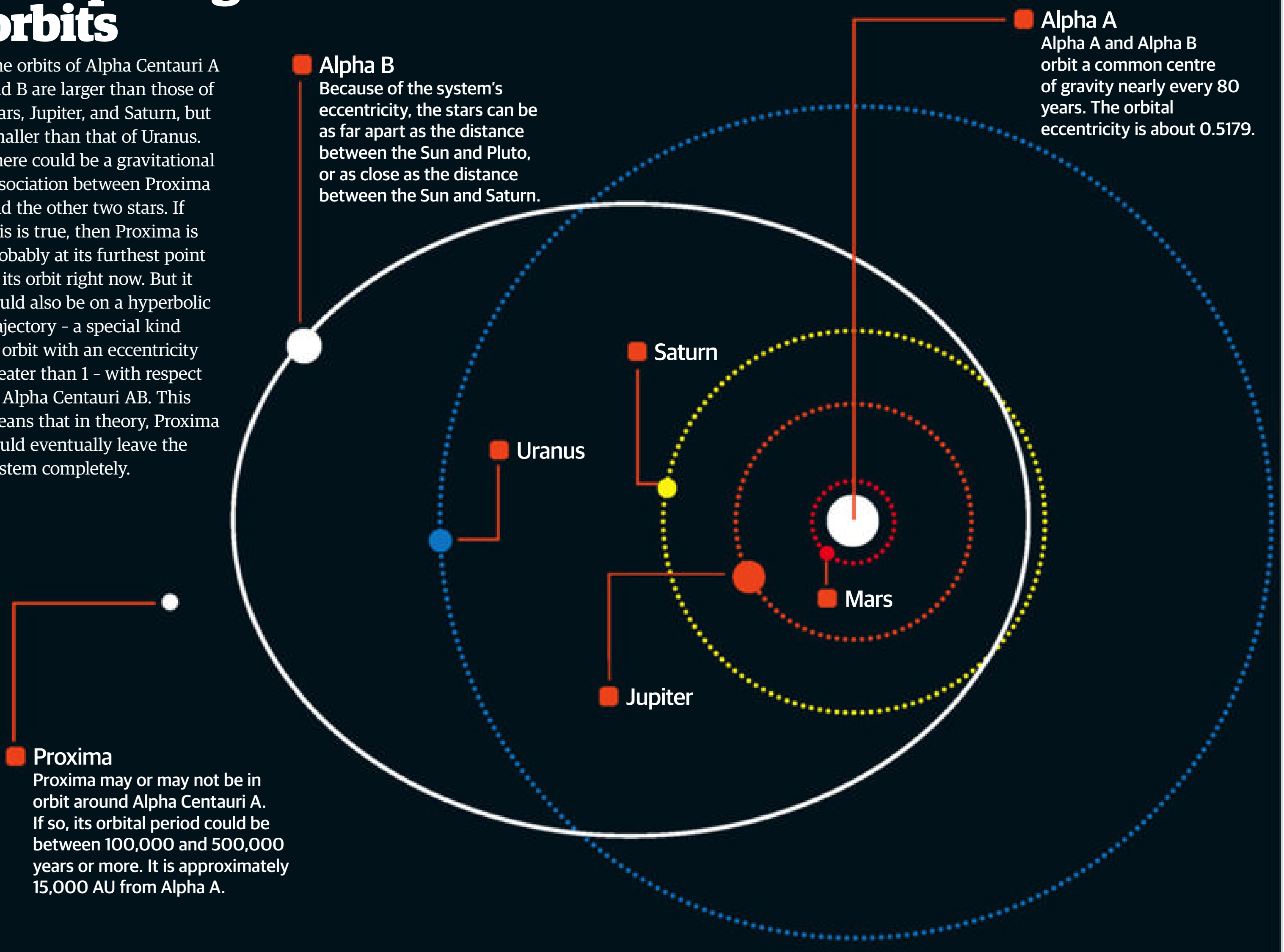
Distance to Proxima Centauri

It may be the closest star after our Sun, but Proxima Centauri is still a very long way from the Earth



Comparing orbits

The orbits of Alpha Centauri A and B are larger than those of Mars, Jupiter, and Saturn, but smaller than that of Uranus. There could be a gravitational association between Proxima and the other two stars. If this is true, then Proxima is probably at its furthest point in its orbit right now. But it could also be on a hyperbolic trajectory - a special kind of orbit with an eccentricity greater than 1 - with respect to Alpha Centauri AB. This means that in theory, Proxima could eventually leave the system completely.

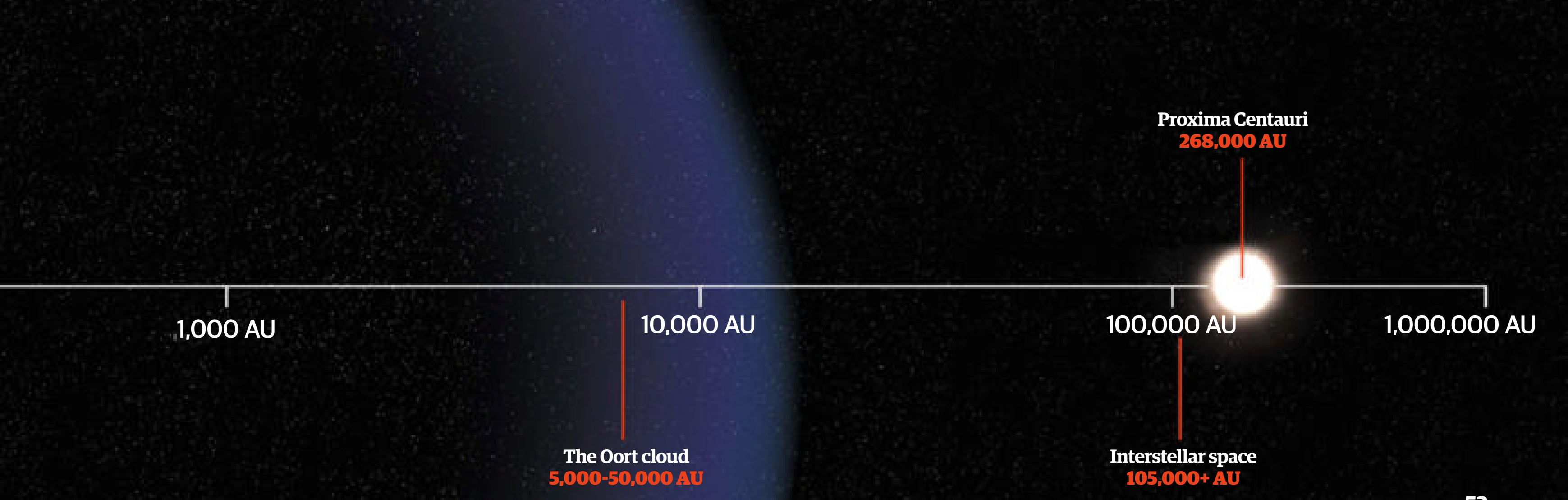


Alpha A
Alpha A and Alpha B orbit a common centre of gravity nearly every 80 years. The orbital eccentricity is about 0.5179.

Alpha B
Because of the system's eccentricity, the stars can be as far apart as the distance between the Sun and Pluto, or as close as the distance between the Sun and Saturn.

Proxima
Proxima may or may not be in orbit around Alpha Centauri A. If so, its orbital period could be between 100,000 and 500,000 years or more. It is approximately 15,000 AU from Alpha A.

1 AU = 150 million kilometres (93 million miles)



Proximа Centauri
268,000 AU

The Oort cloud
5,000-50,000 AU

Interstellar space
105,000+ AU

Proxima: inside and out

The closest star to our Solar System is also one of the dimmest and smallest red dwarfs

Proxima Centauri isn't just a red dwarf; it's on the lower end of range for late-type M-class stars with a mass of just 0.123 that of the Sun. They have dense, opaque interiors. Because of this, late-type red dwarfs have no radiative zone – an area outside the core where energy is transferred via radiation present in other types of stars. Instead, both the core and the outer layer, or envelope, are convective. Energy and hydrogen circulate freely. These types of red dwarfs continue to fuse hydrogen into helium in their cores until it's depleted. In contrast, the Sun will only use up about ten per cent of its hydrogen supply before it leaves the main sequence and goes into a red giant phase.

Compared to larger, more massive stars, the fusion process in red dwarfs is incredibly slow. As a result, the estimated life span of red dwarfs is longer than the age of the universe. The lower the mass of the star, the longer its lifetime, so Proxima's estimated life span is approximately 4 trillion years. As the hydrogen fuel is depleted, the core will contract and it will become a blue dwarf as its temperature rises to up to 8,200 degrees Celsius (14,800 degrees Fahrenheit) and its luminosity increases, giving it a blue appearance. Once the fuel is gone, Proxima Centauri will become a stellar remnant – first a white dwarf, and then a black dwarf as it no longer emits heat or light. Due to their lengthy life span, the life cycle of a red dwarf is theoretical.

> "It's one of the most active flare stars ever observed"

Proxima Centauri is also one of the most active flare stars ever observed, generating X-ray emissions similar to those that come from the Sun. This means that on occasion it can suddenly have flashes of intense brightness. Proxima Centauri's flares are a release from its magnetic field, generated by the convection in the star's interior.

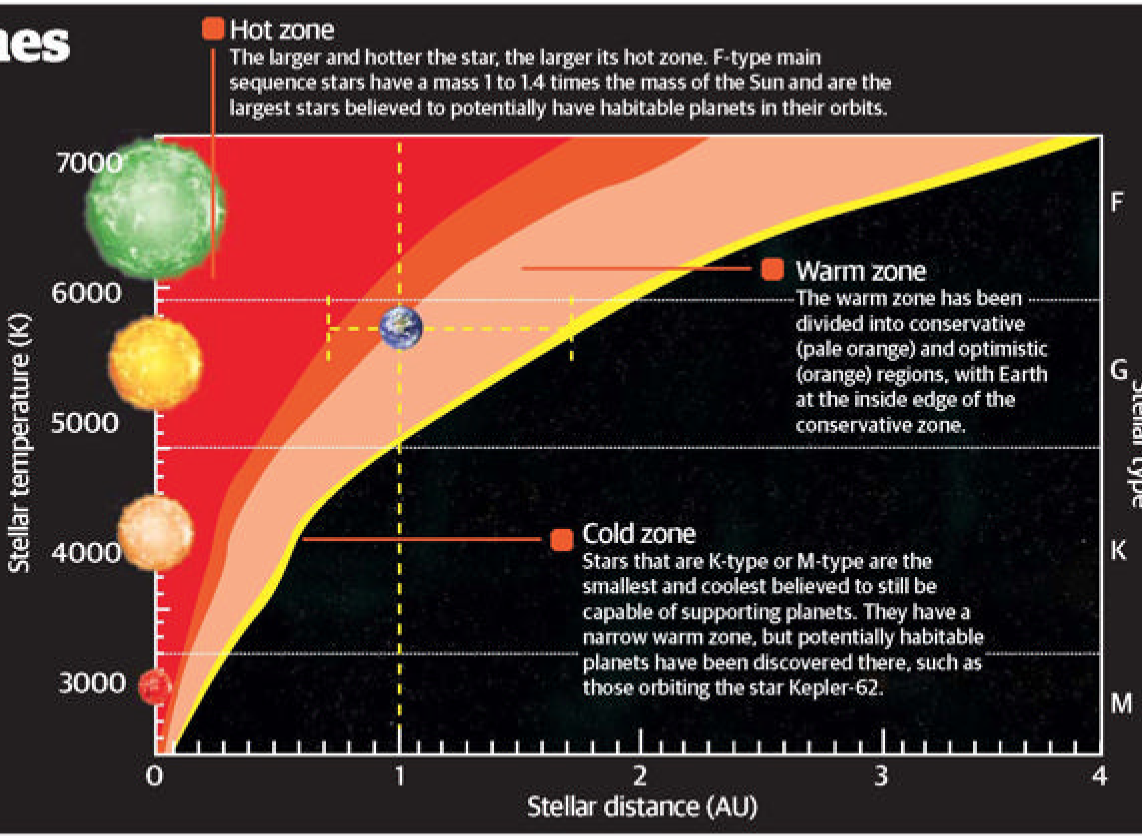
Some scientists have speculated that there is a habitable zone around Proxima Centauri, which would theoretically be a range of about 3.4 million to 8 million kilometres (2 million and 5 million miles) from the star, with an orbital period between 3.6 and 14 days. Red dwarfs emit very little light, and any planet in this zone would probably be tidally locked to the star – with one side remaining in perpetual darkness. This means that there may just be a small region on the planet that is actually habitable, or there would need to be a very thick atmosphere to keep the 'dark' side's temperatures up. In addition, a planet orbiting Proxima Centauri would need to have a strong magnetic field to counteract the effects of the star's flares on its atmosphere.

Other potential challenges include weather and winds, both of which may be harsh; and photosynthesis, which could be a very different process since red dwarfs emit most of their radiation in infrared light instead of visible light. One thing that red dwarfs have going for them is their long life; perhaps even if there isn't a habitable zone around Proxima Centauri now, there could be in the future. During the blue dwarf phase the star will be hotter and brighter, possibly allowing for previously uninhabitable planets to become habitable. ■

Habitable zones

The habitable zone comprises areas around stars where life is theoretically possible on the orbiting planets. It is sometimes known as the circumstellar habitable zone, or the Goldilocks Zone because the circumstances are 'just right' – neither too hot nor too cold – for liquid water to be present on the planet's surface. In addition to temperature, there must also be adequate atmospheric pressure. While this seems simple enough, defining parameters for a habitable zone can be challenging. For our Solar System, estimates range from an inner edge of 108 million km (67 million miles) to an outer edge of 448 million km (278 million miles).

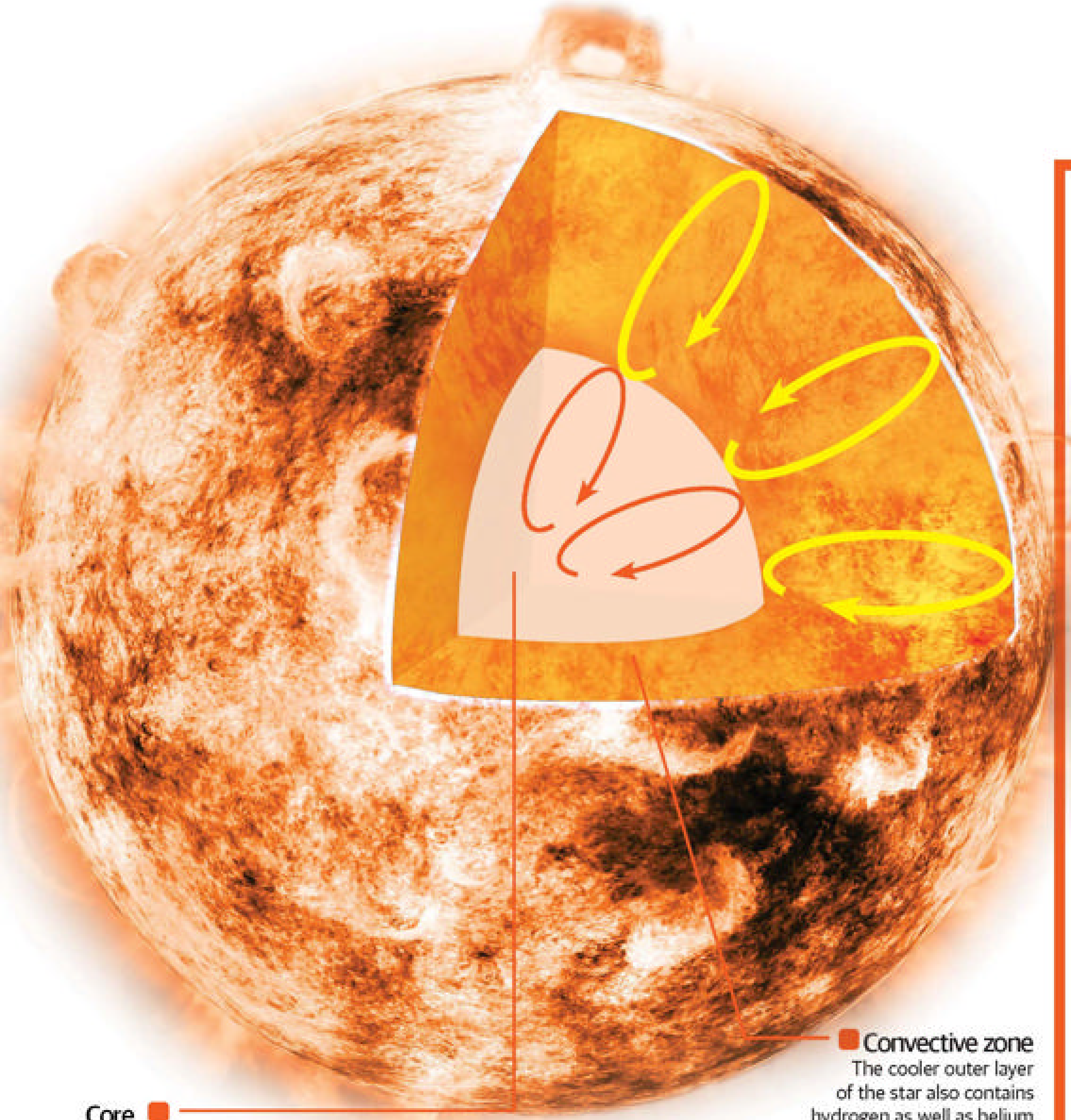
As for other solar systems, estimates for the number of habitable planets vary widely – from 500 million to over 150 billion. Some scientists point out that basing the criteria on our own biosphere amounts to carbon chauvinism – the assumption that all extraterrestrial life is carbon-based like life on Earth.



Hot zone
The larger and hotter the star, the larger its hot zone. F-type main sequence stars have a mass 1 to 1.4 times the mass of the Sun and are the largest stars believed to potentially have habitable planets in their orbits.

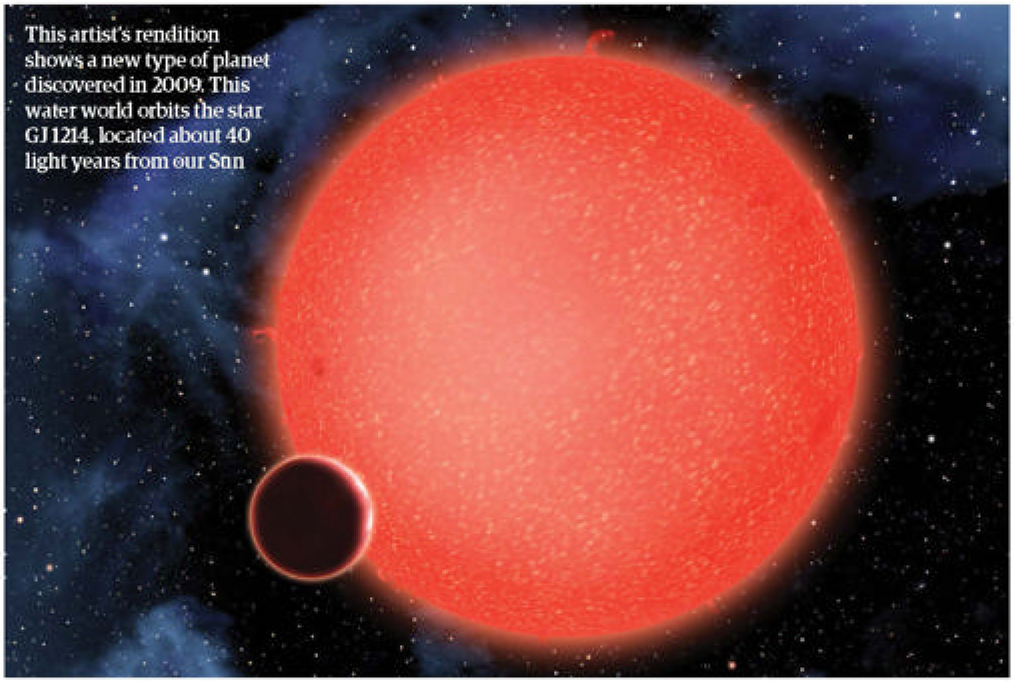
Warm zone
The warm zone has been divided into conservative (pale orange) and optimistic (orange) regions, with Earth at the inside edge of the conservative zone.

Cold zone
Stars that are K-type or M-type are the smallest and coolest believed to still be capable of supporting planets. They have a narrow warm zone, but potentially habitable planets have been discovered there, such as those orbiting the star Kepler-62.



Core
Because red dwarf stars have a low mass, they are entirely convective (without the radiative zone of other stars). Hydrogen fusion takes place within the core and energy moves via circular currents to the outer envelope.

Convective zone
The cooler outer layer of the star also contains hydrogen as well as helium (generated as a result of the fusion process). The hydrogen circulates back to the core, where fusion continues for the lengthy main sequence of the star.



This artist's rendition shows a new type of planet discovered in 2009. This water world orbits the star GJ1214, located about 40 light years from our Sun

Proxima Centauri in numbers

Quick facts and figures about our nearest stellar neighbour

6800

Proxima Centauri is around 6,800 times further from the Sun than Pluto

4 trillion years

Red dwarf stars like Proxima Centauri can last this long because they burn fuel at a slower rate

0.0017

Proxima's total luminosity over all wavelengths is 0.17% that of the Sun

40

Although it's smaller than the Sun in mass and diameter, Proxima is 40 times denser than the Sun

27 million Kelvin

The flares on Proxima Centauri can reach this temperature – hot enough to radiate X-rays

4.24

Light takes this many years to reach the Earth from Proxima

Exploring the stars

Could we travel to this distant neighbour and what problems would we encounter on the way?

Although Proxima Centauri is sometimes referred to as Alpha Centauri C, we aren't yet sure how it fits in with Alpha A and B. The stars in the binary system orbit around a common centre of gravity, and range from being 1.67 billion kilometres (1 billion miles) to 5.3 billion kilometres (3.3 billion miles) apart due to the eccentricity of their orbit. They're relatively similar and Sun-like.

By contrast, Proxima is smaller, redder, weaker and much further from the other two stars. Visually it appears as a faint red star near two very large bright stars - it doesn't seem to fit. However, Proxima has the same proper motion as Alpha Centauri AB; the angular changes in position over time are the same. Proxima could have been pulled into the system by the older stars, or formed at the same time.

Alpha Centauri and Proxima Centauri in particular, as the closest star to us after the Sun, is theoretically our first stop once we figure out the particulars of interstellar travel. Although it's close in terms of stars, the distance is the biggest challenge. We could get there, but it's going to take a long time. Using our current technology, it would take thousands of years. The Voyager 1 space probe has travelled further than any other, and is currently travelling in previously unknown space territory at around 60,000 kilometres per hour (38,000 miles per hour). If it were heading to Proxima, Voyager would take more than 70,000 years to reach the star.

In 2011, NASA's Ames Research Center and the Defense Advanced Research Projects Agency (DARPA) began collaborating on the 100-Year Starship Project. The purpose was to determine the requirements for meeting the goal of human interstellar travel within a century. Some currently feasible ways of reaching Proxima include ion propulsion engines and solar sails. The former creates thrust by accelerating ions, while solar sails harness radiation pressure of gases to push thin, sail-like mirrors to high speeds. Both concepts have been tested, but have not yet been used as a primary source of power.

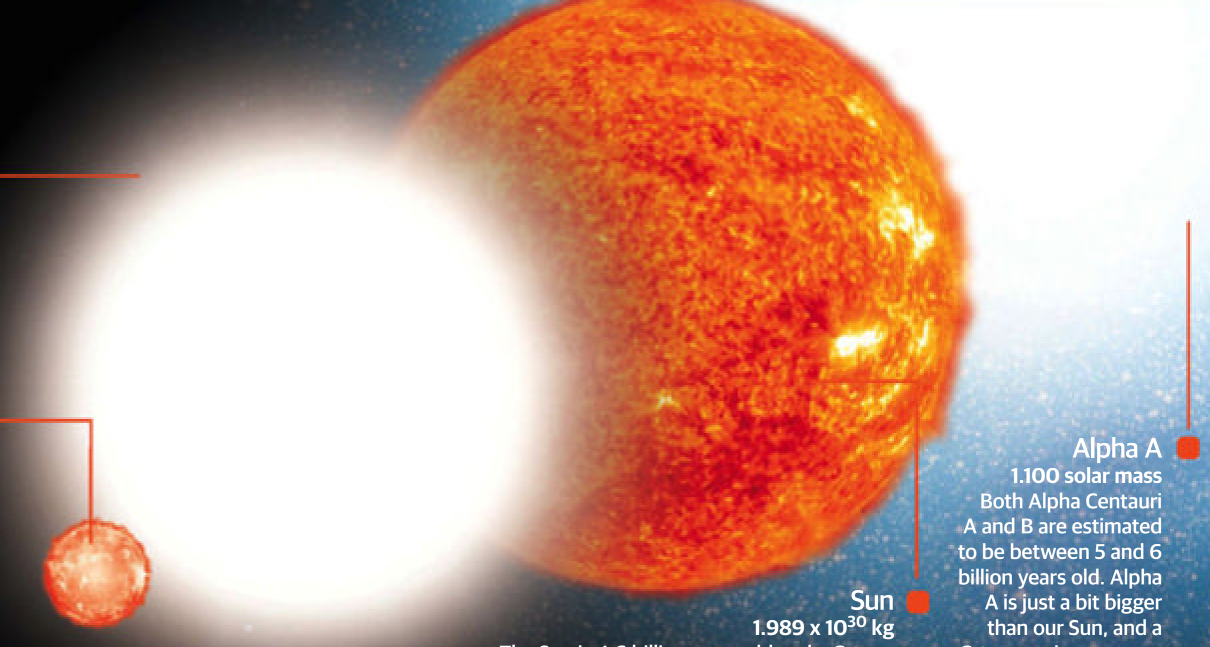
There is also a human cost to interstellar travel. If it's not possible to reduce the amount of time it takes to reach Proxima, we'd need multiple generations of astronauts; children would be born along the way and have to pick up where their parents left off. Even if we could get there in a century, that's longer than the average human lifetime. Space travel also causes bone and muscle loss, and the cardiovascular system loses some of its efficiency. There's also the matter of supplying and maintaining a spacecraft for a number of astronauts, for the trip there and back. Distance is just one challenge on our quest to reach the stars. ■

Seeing the star

Proxima Centauri might be a relatively small and dim star (being a red dwarf), but that doesn't mean it's only visible to the most sensitive telescopes - it can even be seen with a pair of binoculars from Earth. However, because it's so close to Earth it has become a subject of exoplanet hunters in recent years and for that you need some serious hardware, well beyond the most fervent of amateur stargazers. Since the hunt for exoplanets escalated among the space agencies in the Nineties, Hubble, ALMA and Kepler have trained their instruments on this nearby star.

NASA's Hubble Space Telescope (inset) and the European Southern Observatory's ALMA (Atacama Large Millimeter/submillimeter Array) in Chile, are among the most famous of the observatories that have scrutinised Proxima Centauri

Mass matters



Alpha B

0.907 Solar mass

As the secondary star in the system, Alpha B is slightly smaller. It is more orange and a K-type main sequence star – cooler than Alpha A and the Sun.

Proxima

0.123 Solar mass

Proxima Centauri is tiny in comparison to the other stars in the Alpha Centauri system. It is about 4.85 billion years old; potentially older than our Sun but a great deal smaller. It's an M-type star, either main-sequence or sub-dwarf.

Sun

1.989 x 10^{30} kg

The Sun is 4.6 billion years old and a G-type main sequence star, sometimes called a yellow dwarf. It's very similar to Alpha Centauri A.

Alpha A

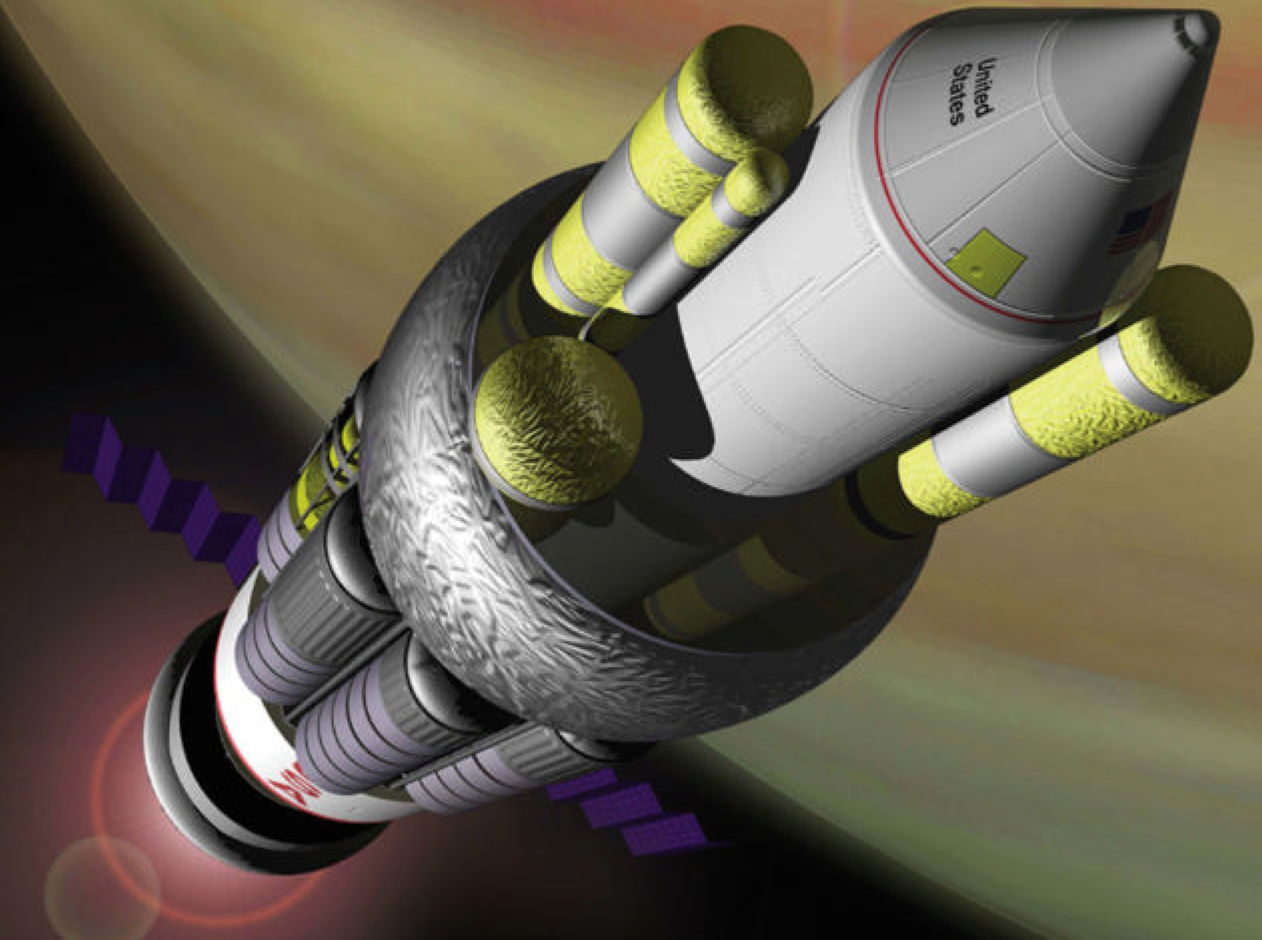
1.100 solar mass

Both Alpha Centauri A and B are estimated to be between 5 and 6 billion years old. Alpha A is just a bit bigger than our Sun, and a G-type main sequence star with a similar yellow colour.

Interstellar travel

We've long been studying ways to achieve interstellar travel. In the late-Fifties, NASA had Project Orion. This spacecraft would have used nuclear pulse propulsion – a series of exploding atomic bombs – to propel it the distance needed to reach Mars, Saturn and ultimately another star. The British Interplanetary Society studied the possibility of a spacecraft to the stars in the Seventies, called Project Daedalus. Daedalus had the goal of taking no longer than a human lifetime to reach its destination, requiring a speed greater than the capabilities proposed for Project Orion. It would have needed a very powerful fusion rocket. Then, in the late-Eighties, NASA tried again with Project Longshot, an unmanned probe designed to be built and launched at Space Station Freedom, the predecessor to the International Space Station. Instead of a closed fusion rocket for power, Longshot would have used a nuclear fission reactor.

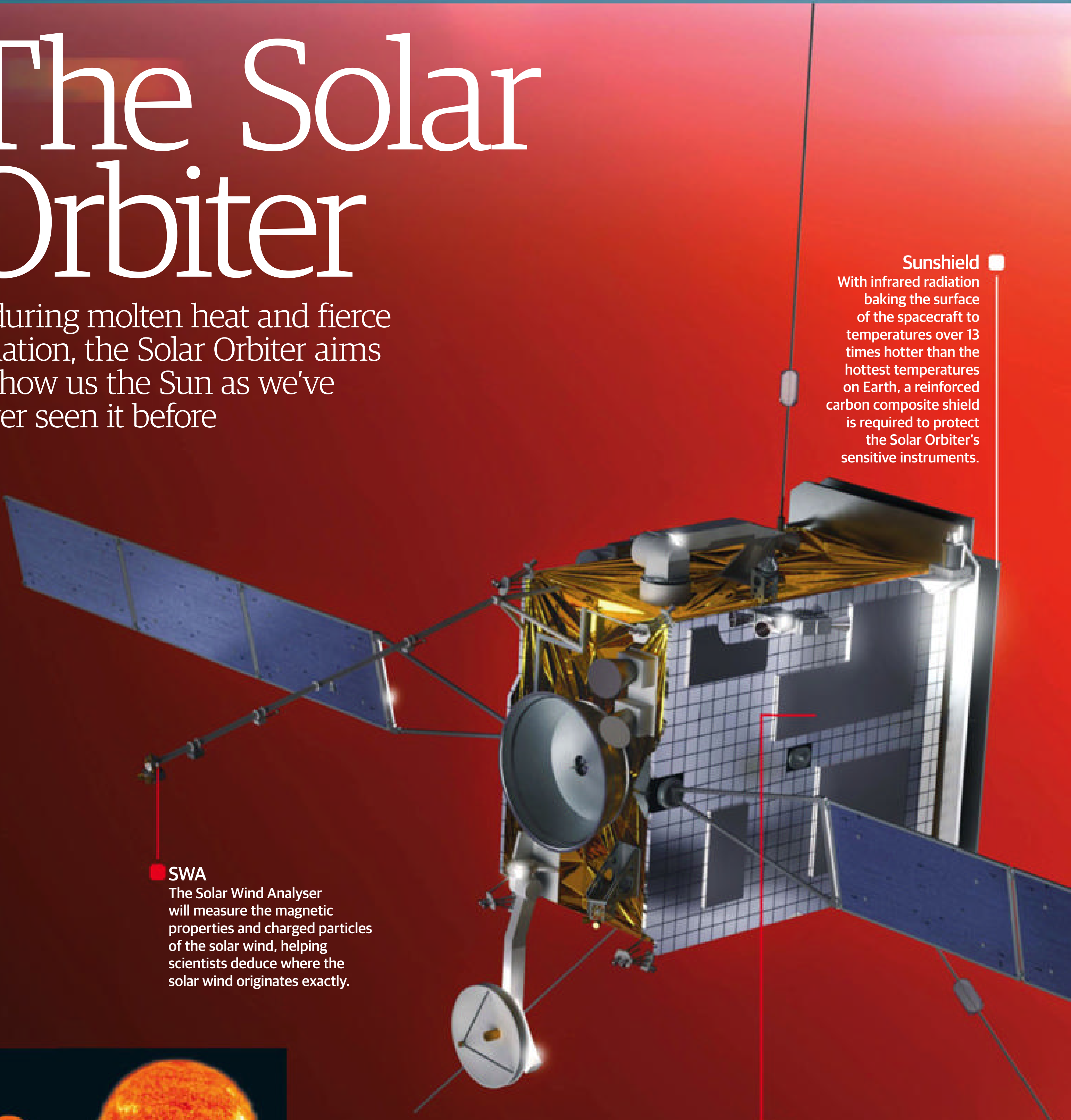
So what happened to keep these projects concept only? For Orion, the Partial Test Ban Treaty, signed in 1963, rendered it impossible. The treaty banned the test detonation of nuclear weapons, except underground. Both Project Daedalus and Project Longshot require significant advances in nuclear fission technology to be viable. Today we don't have the ability to get to Proxima Centauri in less than a thousand years, much less a hundred years.



This artist's rendering shows NASA's Project Orion, a spacecraft study in the Sixties that had aspirations of interstellar travel

The Solar Orbiter

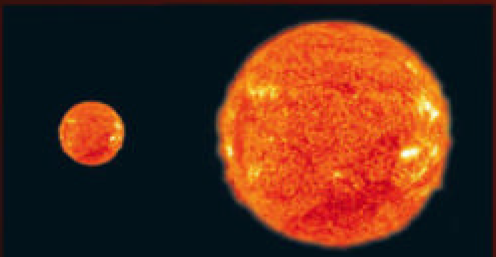
Enduring molten heat and fierce radiation, the Solar Orbiter aims to show us the Sun as we've never seen it before



Sunshield
With infrared radiation baking the surface of the spacecraft to temperatures over 13 times hotter than the hottest temperatures on Earth, a reinforced carbon composite shield is required to protect the Solar Orbiter's sensitive instruments.

SWA
The Solar Wind Analyser will measure the magnetic properties and charged particles of the solar wind, helping scientists deduce where the solar wind originates exactly.

EUI
The EUV full-Sun and high-resolution Imager will take the most detailed images of the Sun's atmosphere that we've seen so far, moving through individual layers right down to the surface.



The Sun, as seen from Earth (left, at 1 AU) and where the Solar Orbiter will be (right, at 0.284 AU)

The Solar Orbiter will use specialised shields and solar arrays to withstand the radiation and heat from the Sun

Solar arrays

The Solar Orbiter's solar arrays, which will power its instruments and systems, have to be of a similar construction to the heat shield and communications, in order to withstand the heat.

The Sun has been subject to detailed scientific scrutiny for decades now. The many filtered images from both terrestrial and orbital telescopes aside, NASA launched the Helios spacecraft in the mid-Seventies to enter an elliptical orbit around the Sun, Helios 2 achieving a world speed record (relative to the Sun) at 252,792 kilometres per hour (149,967 miles per hour).

The Helios spacecraft ceased transmitting data in 1985, however, so the European Space Agency is developing its own solar-orbiting spacecraft, with some international collaboration that includes NASA, who is providing the launcher and some of the scientific instruments the Solar Orbiter will be equipped with.

The spacecraft is scheduled to launch on the back of an Atlas V launch system from NASA's Kennedy Space Center in Florida in 2017. Once it has reached space, the Solar Orbiter will separate from its launch vehicle and travel to within 45 million kilometres (28 million miles) of the Sun. That's just beyond the orbit of Mercury and close enough to potentially rival, even beat the world record shortest distance from the Sun (43.4 million kilometres/26.9 million miles) for any man-made vehicle, set by Helios 2 in 1976. Here, under sweltering heat that bakes the daytime side of Mercury to temperatures easily hot enough to melt lead, plus lethal bursts of atomic particles, the Solar Orbiter will swivel its sunshield to permanently face the Sun and deploy a battery of instruments.

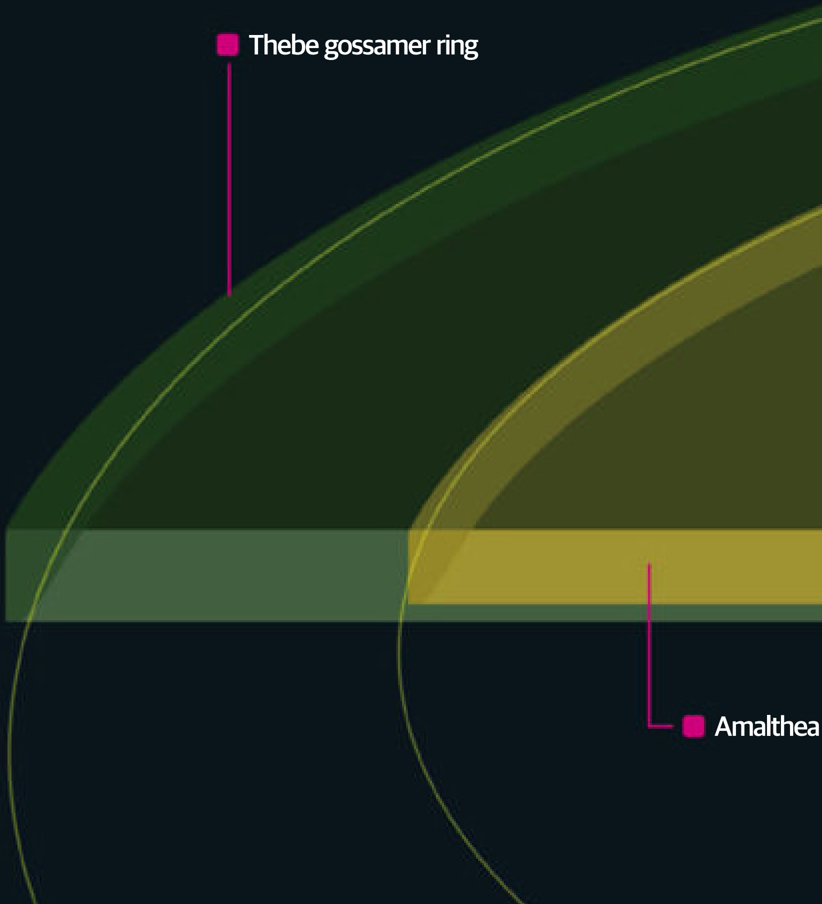
Its scientific payload consists of a set of sophisticated instruments weighing in at 180 kilograms (397 pounds), divided into two observational packages. The heliospheric in-situ instruments will scan the Sun's surface and its atmosphere and includes a high-resolution imager, which will reveal 180-kilometre (111.8-mile) wide solar landscapes in stunning detail that will fascinate both scientists and the public alike. These images alone should enable scientists to glean new insight into the workings of the Sun, while we'll be able to see gases swirl and react in the powerful magnetic fields on the surface. The remote-sensing instruments will measure the charged particles and magnetic fields immediately around the Solar Orbiter itself, which includes taking measurements of the solar wind in close proximity to its source.

The objectives of the Solar Orbiter across the duration of its seven-year main mission include discovering how solar eruptions produce the energetic particle radiation that fills its heliosphere and where the solar wind originates from within the corona. Of course, that does involve wowing us with insanely detailed images of the Sun, too.

© Adrian Mann; NASA

The rings of Jupiter

Did you know that Jupiter has rings like Saturn? Only recently have we been able to study them

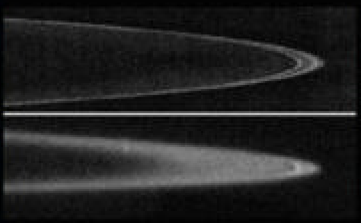


The gas giants Jupiter and Saturn have been known about and observed since ancient history. During the Renaissance period and with the dawn of the telescope, Saturn was characterised by its mesmerising ring system whereas Jupiter was the hulking brute of the Solar System, known for the swirling tempest blooming on its south equatorial belt that was later dubbed the Great Red Spot. Scientists identified a similar ring system on Uranus, so when Voyager 1 began its flyby of Jupiter in early 1979, NASA tasked it to look specifically for rings – and it found some. Nearly 20 years later, the Galileo probe entered orbit around Jupiter and was able to study its rings in detail, while New Horizons was able to take high-resolution images revealing the structure of the main ring in its spring 2007 flyby.

Jupiter's rings are made of four parts and are composed mainly of fine dust of varying grades. A thick 'halo' ring orbits the innermost Jovian region, followed by the bright main ring, and the two faint gossamer rings. These gossamer rings are made up of the dust ejected from the two moons, Thebe and Amalthea, which orbit within them, a result of high-energy impacts kicking up debris from their surfaces. The biggest of Jupiter's rings is the Thebe gossamer ring, which has a radius of around 226,000 kilometres (140,000 miles), a width of 97,000 kilometres (60,000 miles) and a thickness of 8,400 kilometres (5,000 miles).

The rings themselves might have existed as long as Jupiter, although the lifetime of the tiny dust particles in the main ring could be anything from 100 to 1,000 years. It's continuously being removed from the ring by the Jovian magnetosphere and replenished by impacts between larger objects that are anything from a single centimetre (0.4 inches) up to 500 metres (1,640 feet) in diameter.

> "When Voyager 1 began its flyby of Jupiter in early 1979, NASA tasked it to look specifically for rings – and it found some"

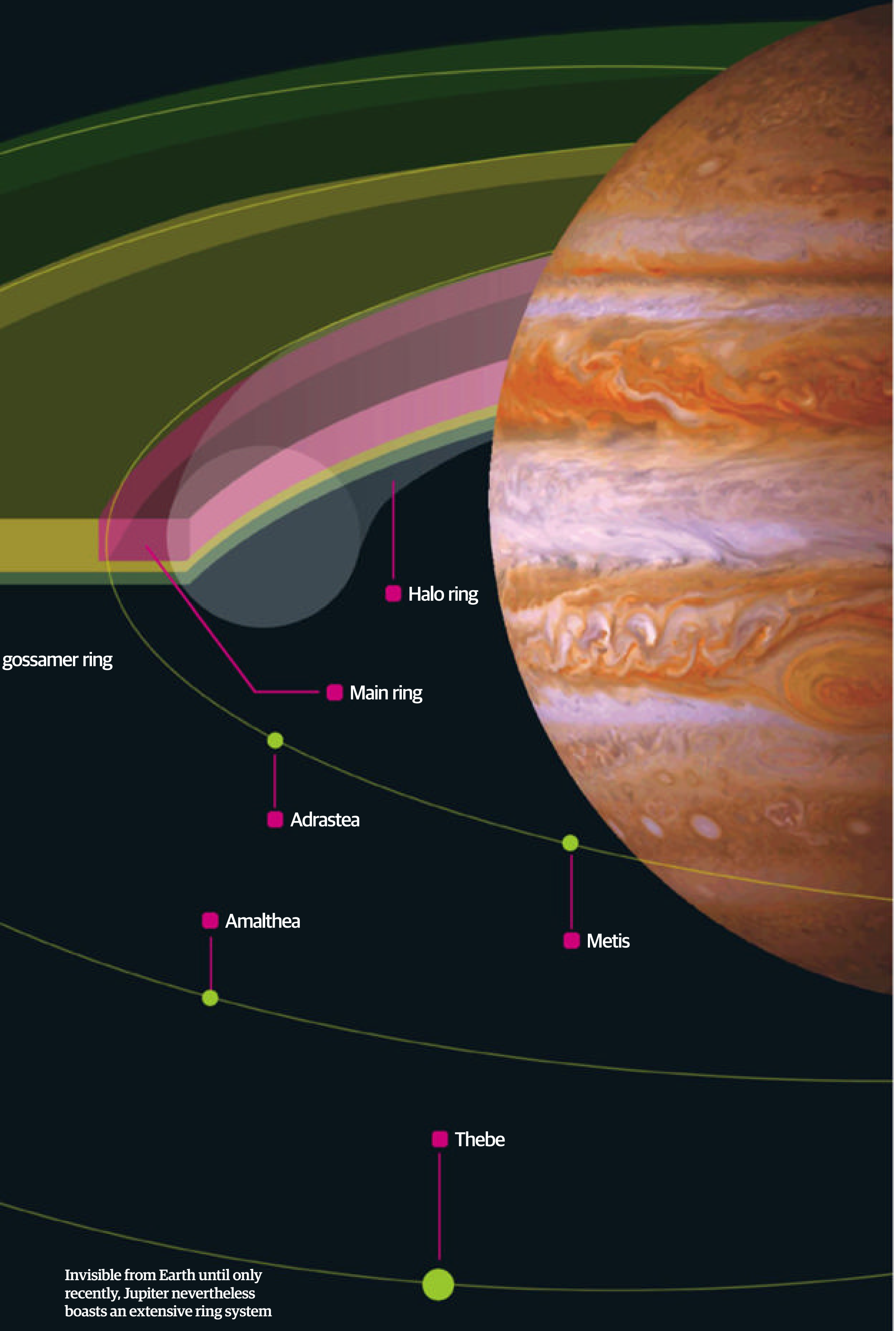


Planetary rings

There are several theories of how large planetary rings of this type are formed. One theory is that they're the remnants of the protoplanetary disc that formed the planet, left within a region that was unable to form a moon (known as the Roche limit). Another is that they're the remains of a moon either torn apart by the tidal stresses of large planets such as Jupiter, or destroyed by a massive impact. Smaller and fainter rings can form from multiple impacts into the surface of moons orbiting a planet or from a volcanic eruption, such as the E-ring of Saturn, which formed out of the cryovolcanic ejecta from Enceladus's volcanoes. In around 50 million years' time, the Martian moon Phobos is likely to be pulled apart into a ring because of its low orbit. Since the discovery of rings around Uranus, Neptune and Jupiter, scientists have been looking closely at other celestial bodies such as the Saturnian moon Rhea and Pluto, to see whether they have rings, too.

Ring breakdown

What are Jupiter's rings made of, how big are they and how were they formed?



Invisible from Earth until only recently, Jupiter nevertheless boasts an extensive ring system

Halo ring

The innermost halo ring stretches from around 92,000km (57,000 miles) to just over 120,000km (78,000) and is the thickest of Jupiter's rings through the vertical. It's shaped like a torus and is significantly less bright than the main ring despite being many times wider and thicker. The dust particles that the Halo ring is composed of are less than 15 micrometres in diameter and are mostly derived from the main ring.

Main ring

This narrow ring is just 6,500km (4,000 miles) wide and stretches from 122,500km (76,000 miles) and 129,000km (80,000 miles). It's the brightest of the rings and fringes on Adrastea, the smallest of Jupiter's four inner moons. The main ring's dusty composition isn't evenly distributed and is divided into regions of varied thickness that scatter light more effectively than the other rings. Still, it was faint enough to be missed by the Hubble Space Telescope and wasn't detected until Keck viewed it in 2002.

Amalthea gossamer ring

The innermost gossamer ring runs from the border of the main ring to around 182,000km (113,000 miles), decreasing in thickness towards Jupiter. The ring gets its name from the Jovian moon Amalthea, a 160km (99 mile) diameter rock that orbits right through the centre of the Amalthea gossamer ring. As it passed through the gossamer rings in 2002, the Galileo spacecraft detected small bodies of less than 1km (0.6 miles) near Amalthea, which are likely the debris caused by numerous collisions.

Thebe gossamer ring

Like Jupiter's other rings, the Thebe gossamer ring is composed of dust from impacts with the Jovian moons. It's the faintest of the rings and stretches far out to the orbit of the moon of Thebe at 226,000km (140,000 miles). However, scientists are unable to explain the extension of the Thebe ring's orbit, which could be due to the influence of Jupiter's magnetosphere or even objects on the outside of the Thebe ring that are as yet unseen.

© NASA

Asteroid Mining

Several companies have announced plans to harvest the resources of asteroids for use both on Earth and in space, but how would it be done and is it truly feasible?

Written by Jonathan O'Callaghan

For the last year or so asteroid mining has been one of the most talked about topics in space exploration. Not only have two start-up companies, Planetary Resources and Deep Space Industries (DSI), announced plans to begin the extraction of resources in the future, but NASA has also revealed its intention to begin the exploration of asteroids and return useful samples to Earth. The public have been laden with awe-inspiring concept imagery and fantastical mission proposals that have garnered attention around the world but, the question is, can it really be done?

Most asteroids we know of reside in the asteroid belt between Mars and Jupiter but a few thousand known as near-Earth objects can be found in the inner Solar System. Based on studies of meteorites on Earth and observations of asteroids, we know a lot of these objects are rich in certain types of metal and potentially water. Some of these asteroids are drifting on elliptical orbits around the Sun that bring them between the Earth and the Moon, making them a viable destination for future exploration.

It is these near-Earth asteroids that DSI and Planetary Resources intend to target (see 'Missions to mine asteroids' boxout), albeit with slightly different goals. Both companies intend to prospect asteroids before visiting them, but while Planetary Resources wants to mostly retrieve resources from asteroids and return them to Earth, DSI instead intends to directly utilise asteroid minerals in space.

"As all space programme enthusiasts and particularly engineers and designers will know, it's extremely expensive to get things into space," says Geoff Notkin of Discovery Channel's *Meteorite Men* and a member of the advisory board for DSI. "The cost is prohibitive for us to build large exploration vessels to explore deep space. But what if we could harvest the raw materials that we need to build spacecraft and other technological wonders in space? That is our primary goal."

Planetary Resources, meanwhile, will bring minerals back to Earth to be used on our planet, although it too has plans to utilise resources like water in space. Its reasoning is that metals such as platinum and gold are ripe to be harvested from particular asteroids, and bringing them back could have huge monetary values. Some estimates suggest that asteroids could be worth multiple billions of dollars, or perhaps even trillions, in modern Earth markets. There are a huge amount of unknowns, though. How easy will it to be to extract these useful minerals from an asteroid? And are we even sure that asteroids will contain these amounts of useful resources?

"By examining meteorites that have landed on Earth, we can get very valuable clues regarding what asteroids are made up of," says Notkin. "We've found many different elements in meteorites that have landed. Of course, they are the same elements that we find in terrestrial rocks but the mixtures are different, and so the meteorites are typically rich in nickel, for example, and that could be a valuable resource for us. And then we've had some asteroid flybys and by examining the spectroscopy of asteroids via telescopes we can get a fairly good [idea] of their composition. The next step is to

The Active Response Gravity Offload System (ARGOS) helps NASA train future astronauts for manned asteroid missions

NASA's Desert Research and Technology Studies (RATS) tests technologies that may be used for missions to asteroids

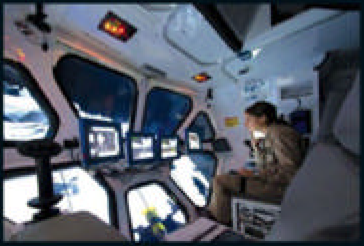
Missions to mine asteroids

NASA

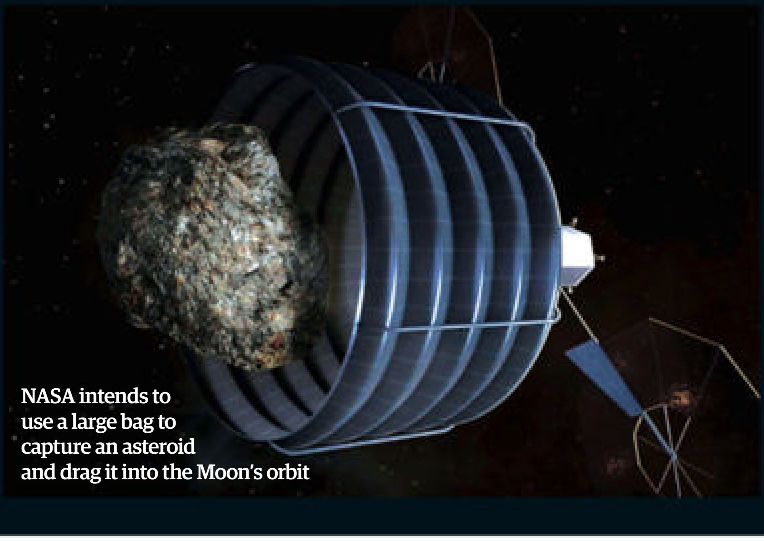
In NASA's 2013 budget it announced a proposal to capture an asteroid and drag it into a stable lunar orbit to be visited by future astronauts. It might sound far-fetched, but the technology behind it is relatively simple.

The plan is to launch a spacecraft powered by ion thrusters, which will then make its way to an asteroid beyond the Moon. Once reaching its target, the spacecraft would capture the asteroid in a large bag and, over a number of years, move it into a stable orbit around the Moon. This could then be visited and studied by astronauts in the future, possibly on NASA's Orion spacecraft.

Aside from this asteroid capture mission, NASA also has an upcoming mission known as the Origins-Spectral Interpretation Resource Identification Security Regolith Explorer (or OSIRIS-Rex for short). This unmanned spacecraft will launch in 2016 to an asteroid called Bennu, where it will collect at least 60 grams (two ounces) of surface material in 2018 and return it to Earth in 2023.



The MMSEV simulator has been used to test approaches to an asteroid



NASA intends to use a large bag to capture an asteroid and drag it into the Moon's orbit

Eventually DSI will begin mining large amounts of asteroids to be used in space

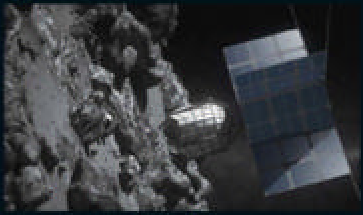
Deep Space Industries

Deep Space Industries (DSI) announced in January 2013 that it intends to start harvesting metals and water from asteroids within the next decade. To do this, it will send prospecting spacecraft into space beginning in 2015 to find suitable asteroids to visit. The low-cost spacecraft, each known as a Firefly, will weigh 25 kilograms (55 pounds) and will share rides into space on rockets with other larger spacecraft.

In 2016, DSI intends to launch larger spacecraft called Dragonflies, weighing 32 kilograms (77 pounds). They will retrieve samples from asteroids prospected by the Firefly spacecraft on missions lasting two to four years.

The final component of the mission will be to extract useful resources from asteroids by 2023. Using a 3D printer known as the MicroGravity Foundry, DSI intends to use asteroid resources in space to build new components and machines such as communications satellites and solar power stations, and it also wants to use water from asteroids to manufacture rocket fuel in space. This, DSI says, will drastically reduce the cost of space exploration by allowing us to build new things in space rather than having to launch them from Earth.

DSI first plans to prospect potential asteroids with its Firefly spacecraft



Dragonfly spacecraft will then collect samples from suitable asteroids

A 101kg (222lb) pallasite (stony-iron) piece of asteroid, or meteorite, found by Meteorite Men Geoff Notkin (left) and Steve Arnold (right) on a Kansas farm in 2010

find out which asteroids are right for harvesting, and that's part of Deep Space Industries' plan."

However, Michael Murphy, a freelance mining consultant on Earth, disagrees on the usefulness of asteroid mining. "What are you going to mine that it's in such sort supply and in equally high demand in quantities needed to start these projects?" says Murphy. "I don't know of anything in particularly short supply. I don't think there is anything we can't survive without at the moment."

The potentially huge costs of asteroid mining are also something of concern, and Murphy was quick to point out the pitfalls of mining on our own planet. "On Earth, the costs of building even a railway line are so high that some projects will not even get off the ground. If you compare the price of building a railway to putting a rocket into space, the costs are surely going to be huge. The only things that could potentially justify such large expenditure would be things that would be priceless: remedies for incurable diseases, for example."

To overcome these challenges both companies will have to ensure that their costs remain manageable and their plans are realistic. As Chris Lewicki, the president of Planetary Resources, points out in our interview with him later in this feature, by using smaller teams and focusing less on scientific aspects the companies will be able to run missions to asteroids at a much lower cost than has previously

Planetary Resources

Planetary Resources is a billionaire-backed asteroid mining company - with Google executives Larry Page and Eric Schmidt and movie director James Cameron among its investors - which intends to begin mining asteroids by next decade.

The company's first step will be to launch prospecting telescopes called Arkyd 100 to find suitable asteroids to mine. The technology for these telescopes will be tested by the Arkyd-3 satellites, small CubeSats that will be launched in 2014.

Next up will be the Arkyd 200 telescopes. These will be similar to Arkyd 100 except they will have propulsion capabilities, and therefore will be able to fly by asteroids and survey them in detail to ascertain their suitability for future missions. Following this will be the Arkyd 300 spacecraft, which will not only be able to travel to more distant asteroids but also study them in even greater detail, collecting data on their shape, rotation, composition and more. This will allow Planetary Resources to find asteroids that are particularly suitable for mining.

The last step will be to actually begin asteroid mining. A multitude of low-cost robots will be sent to an asteroid to scour its surface and extract resources to be collected by other spacecraft. Like NASA, Planetary Resources also has ambitions to capture an asteroid and tow it into a position close to Earth so that it can extract more useful resources such as water, which could then be used to produce rocket fuel in space.

Planetary Resources will begin prospecting asteroids with its Arkyd 100 telescopes

Eventually Planetary Resources may capture an asteroid and place it in a position near the Earth for easier access

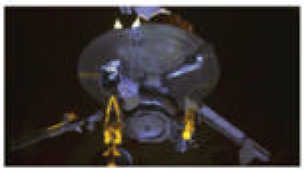
> "We'll be able to send missions to asteroids for just a few million dollars each"
>
> **Chris Lewicki, president of Planetary Resources**

been done. The entirety of NASA's 2016 OSIRIS-Rex mission, for example, which itself will take seven years to complete, will cost close to $1 billion (£665 million), but it'll return just 60 grams (two ounces) of asteroid material. DSI and Planetary Resources, meanwhile, want to mine much larger amounts than that with missions costing a fraction of the price.

There is precedent that such endeavours can be successful at lower costs, but there are major hurdles to overcome. In 2010, the Japanese space agency (JAXA) successfully completed a relatively low-cost mission, estimated at around $100 million (£66 million) to return a sample from an asteroid with its Hayabusa spacecraft. It took JAXA about seven years to return a minuscule amount of material from the Itokawa asteroid, but the mission demonstrated that for a manageable cost it is possible to travel to an asteroid, collect a sample and return to Earth. "It's important to watch what's happening in the space programme and learn from that," says Notkin. "I think every complex mission illustrates the hazards involved."

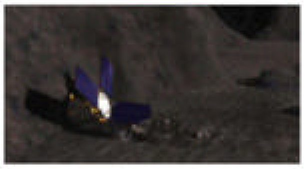
Another way to tackle the monetary issues involved, as outlined by DSI, will be to harvest asteroid resources to be used in space, rather than bringing them back to Earth. "One of the abilities that DSI is developing is the ability to extract raw materials from asteroids and then, using a 3D printer, actually build parts in space," explains Notkin. "So, of course there are other companies who have looked at the concept of bringing raw materials from the asteroids to Earth, but I think our plan is more realistic. We want

Asteroid missions



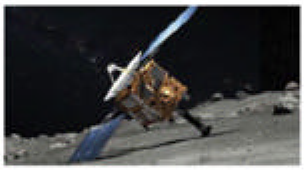
October 1991
Galileo

NASA's Galileo spacecraft flew by asteroid 951 Gaspra on its way to Jupiter, making it the first asteroid to be visited by a spacecraft.



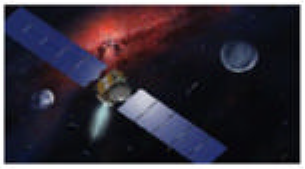
February 2001
NEAR Shoemaker

After completing 230 orbits of asteroid 433 Eros, the NEAR Shoemaker became the first spacecraft to land on an asteroid.



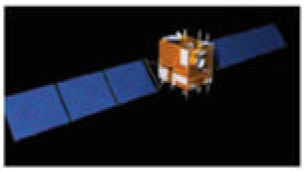
November 2005
Hayabusa

JAXA's Hayabusa probe landed on the Itokawa asteroid before taking off and returning the first samples from the surface of an asteroid to Earth in June 2010.



July 2011
Dawn

The Dawn spacecraft entered orbit around 4 Vesta, the largest asteroid to be orbited by a spacecraft. It left orbit in September 2012.



December 2012
Chang'e 2

The Chinese lunar probe Chang'e 2 flew by asteroid 4179 Toutatis, approaching to within 3.2km (two miles), after completing its operations at the Moon.

Types of asteroid

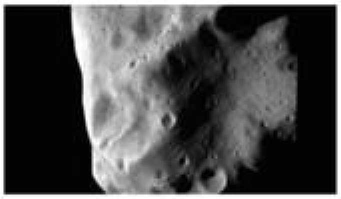
Most asteroids are known to reside in the asteroid belt but, on occasion, they might be drawn into the inner Solar System, for example when Jupiter knocks them out of their orbits. We can study these near-Earth asteroids as they make their way past us, and we've also sent numerous spacecraft to various asteroids to study them in greater detail. Here, we've taken a look at the three main types of asteroid we know of to date.

C-type

Carbonaceous (C-type) asteroids comprise over 75% of all known asteroids. They are dark with a similar composition to that of the Sun, but without most of the hydrogen, helium and other volatiles present in our star. They are mostly found in the outer regions of the asteroid belt.

S-type

Silicaceous (S-type) asteroids account for 17% of all the asteroids we know of and are therefore the second most common type. They're brighter than C-type asteroids and are mostly made of iron and magnesium-silicates. They tend to dominate the inner asteroid belt around Mars.



M-type

Metallic or M-type asteroids make up most of the rest of the asteroids we know of. They're generally slightly dimmer than S-type asteroids and their compositions are dominated by metallic iron. Most of these asteroids hang out in the central region of the asteroid belt.

to use the materials from asteroids in space and not have to bring them back to Earth." On this, Murphy agrees. "In a scenario where you've found an asteroid, you've got the ability to produce parts cheaply, and all these things turn out to make the project economically feasible, then maybe this is a possibility," he says.

One of the greatest applications of asteroid mining, however, might be for something that we have in abundance here on Earth: water. Water

JAXA's Hayabusa demonstrated the concept for landing on an asteroid and returning a sample to Earth

5 reasons we need to mine asteroids

1 They're vital to future missions

While we've carried out some missions to asteroids we've never had a prolonged stay on the surface of an asteroid. Future missions, like NASA's proposal to capture an asteroid and then visit it, would help us learn how to operate in deep space. It would provide us with key information as to how astronauts can operate in minimal gravity environments on long-duration missions, and it just might be a useful precursor to a mission to Mars.

2 We could use them to make rocket fuel

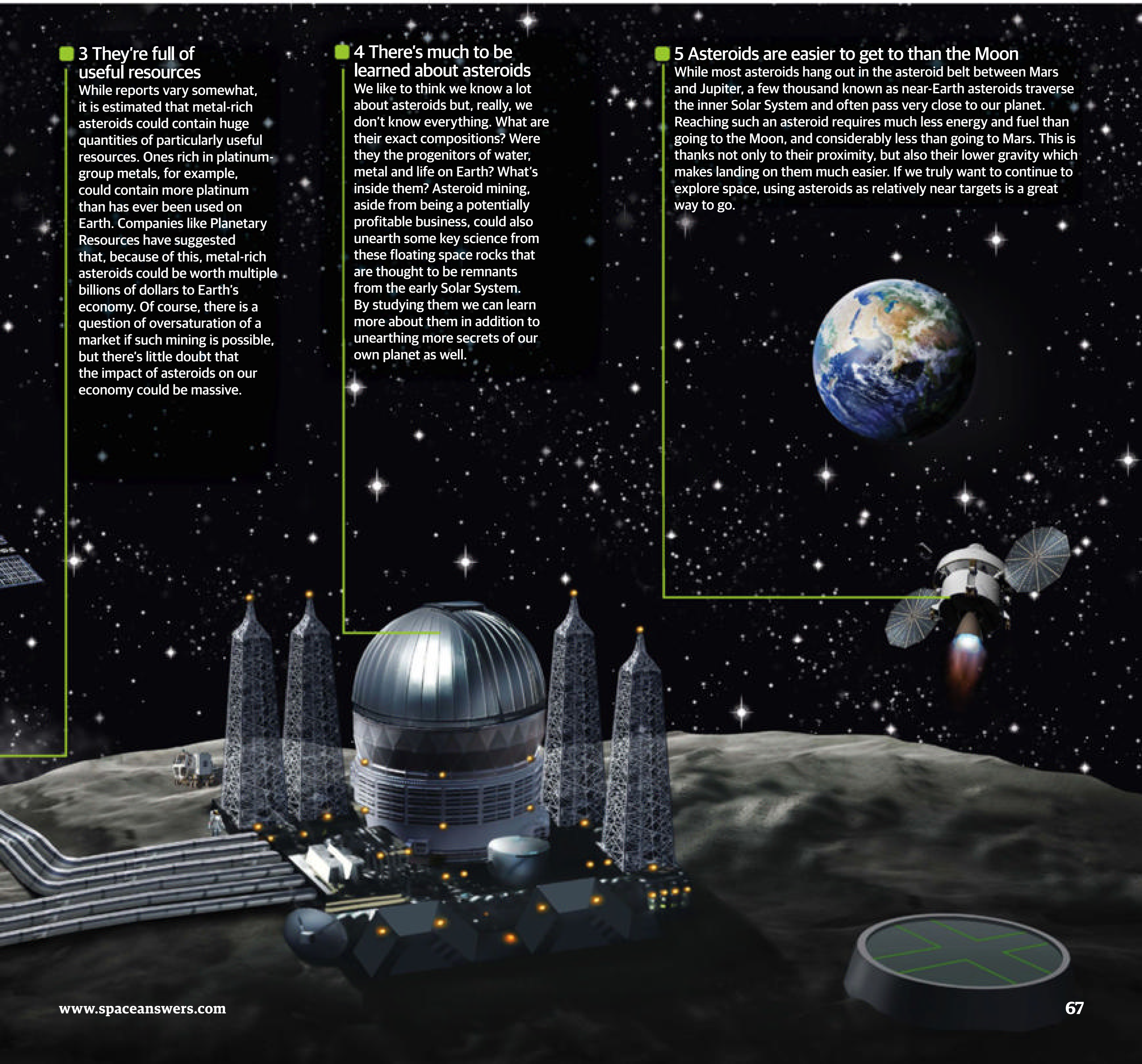
One of the main constraints of space exploration is rocket fuel. The majority of any spacecraft's mass is often taken up by rocket fuel, whether its liquid hydrogen, liquid oxygen or whatever. One common constituent of rocket fuel, however, is water. If we could find water in space, we could hypothetically reprocess it into rocket fuel. And it just so happens that some asteroids are thought to contain vast amounts of water, possibly in the form of ice. If we could harness this water, we could refuel spacecraft in space rather than having to lift all the required fuel into space form Earth, therefore reducing the cost of space exploration.

is not only important for the survival of astronauts but it is also one of the primary constituents of rocket fuel. If an asteroid rich in water could be found, then there's the potential that this could be extracted to be used in space rather than having to lift it at considerable cost from the surface of the Earth. "At the present time everything has to be blasted into space, and that costs thousands of dollars per kilo for everything that needs to go up there," says Notkin.

"So on the one hand there will be the opportunity to actually build spacecraft in space away from the influence of Earth's gravity, so we don't have to fly everything up there by rocket, and secondly there are some very practical short-term applications for these concepts. What if we could produce fuel in space that we could then provide to existing satellites that are in orbit?"

To carry out all of these grandiose mission proposals, DSI and Planetary

This iron meteorite fragment is the remains of an asteroid that formed a crater in the forests of Alberta, Canada about 1,100 years ago



3 They're full of useful resources

While reports vary somewhat, it is estimated that metal-rich asteroids could contain huge quantities of particularly useful resources. Ones rich in platinum-group metals, for example, could contain more platinum than has ever been used on Earth. Companies like Planetary Resources have suggested that, because of this, metal-rich asteroids could be worth multiple billions of dollars to Earth's economy. Of course, there is a question of oversaturation of a market if such mining is possible, but there's little doubt that the impact of asteroids on our economy could be massive.

4 There's much to be learned about asteroids

We like to think we know a lot about asteroids but, really, we don't know everything. What are their exact compositions? Were they the progenitors of water, metal and life on Earth? What's inside them? Asteroid mining, aside from being a potentially profitable business, could also unearth some key science from these floating space rocks that are thought to be remnants from the early Solar System. By studying them we can learn more about them in addition to unearthing more secrets of our own planet as well.

5 Asteroids are easier to get to than the Moon

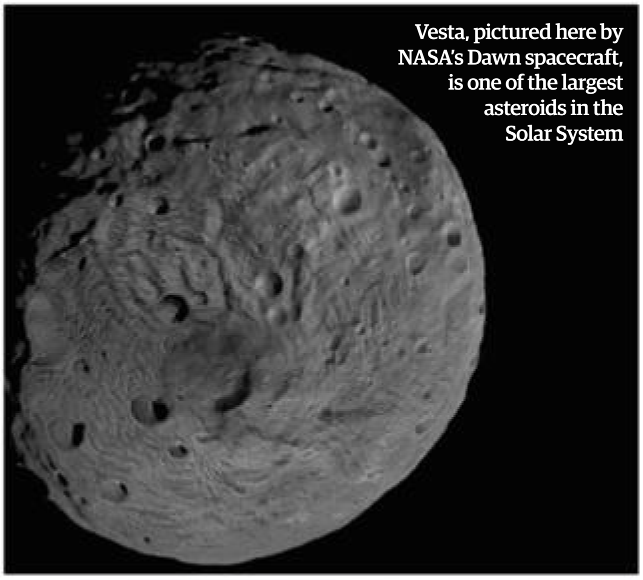
While most asteroids hang out in the asteroid belt between Mars and Jupiter, a few thousand known as near-Earth asteroids traverse the inner Solar System and often pass very close to our planet. Reaching such an asteroid requires much less energy and fuel than going to the Moon, and considerably less than going to Mars. This is thanks not only to their proximity, but also their lower gravity which makes landing on them much easier. If we truly want to continue to explore space, using asteroids as relatively near targets is a great way to go.

> "If, as we believe, these asteroids are rich in raw materials, I'm certain we'll see commercial mining in action in the next 10 to 20 years"
>
> **Geoff Notkin, advisor to Deep Space Industries**

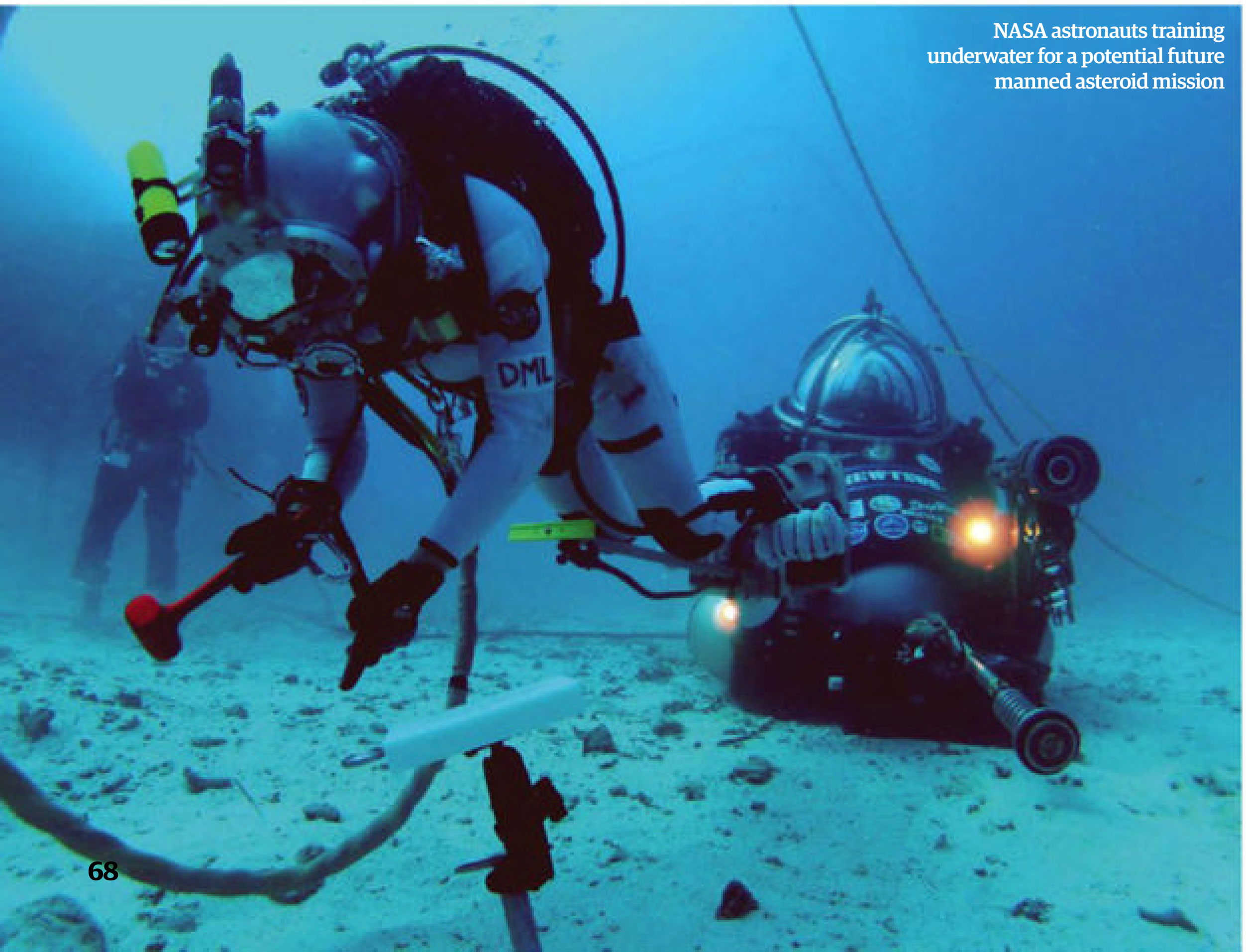
Resources will of course need some pretty advanced technology. Both companies have made sure to hire experts who have previously worked on particularly difficult and challenging space missions; Planetary Resources, for example, has a number of engineers who worked on NASA's Mars exploration programmes. Before any sort of asteroid mining can begin, though, suitable asteroids will need to be found to ensure that any resource extraction returns a useful amount of material that can be utilised in space or brought back to Earth.

"As soon as 2015 we hope to have small robotic spacecraft named Fireflies prospecting asteroids to determine which ones might be suitable for mining," says Notkin. "Once suitable candidates have been located, larger ships known as Dragonflies will begin to extract material from these asteroids. Conceivably this can happen within just a few years; the technology for the most part exists here on Earth, and we've also been working closely with a company that specialises in 3D printing. If we can get that 3D printing technology into space and combine it with the extraction of raw materials that we need from asteroids, we can build spacecraft components in space. They'll never be on Earth, their entire existence will be in space. I find that rather amazing. Almost the stuff of science fiction."

The sample capsule from JAXA's Hayabusa spacecraft, which returned the first sample from the surface of an asteroid in June 2010



Vesta, pictured here by NASA's Dawn spacecraft, is one of the largest asteroids in the Solar System

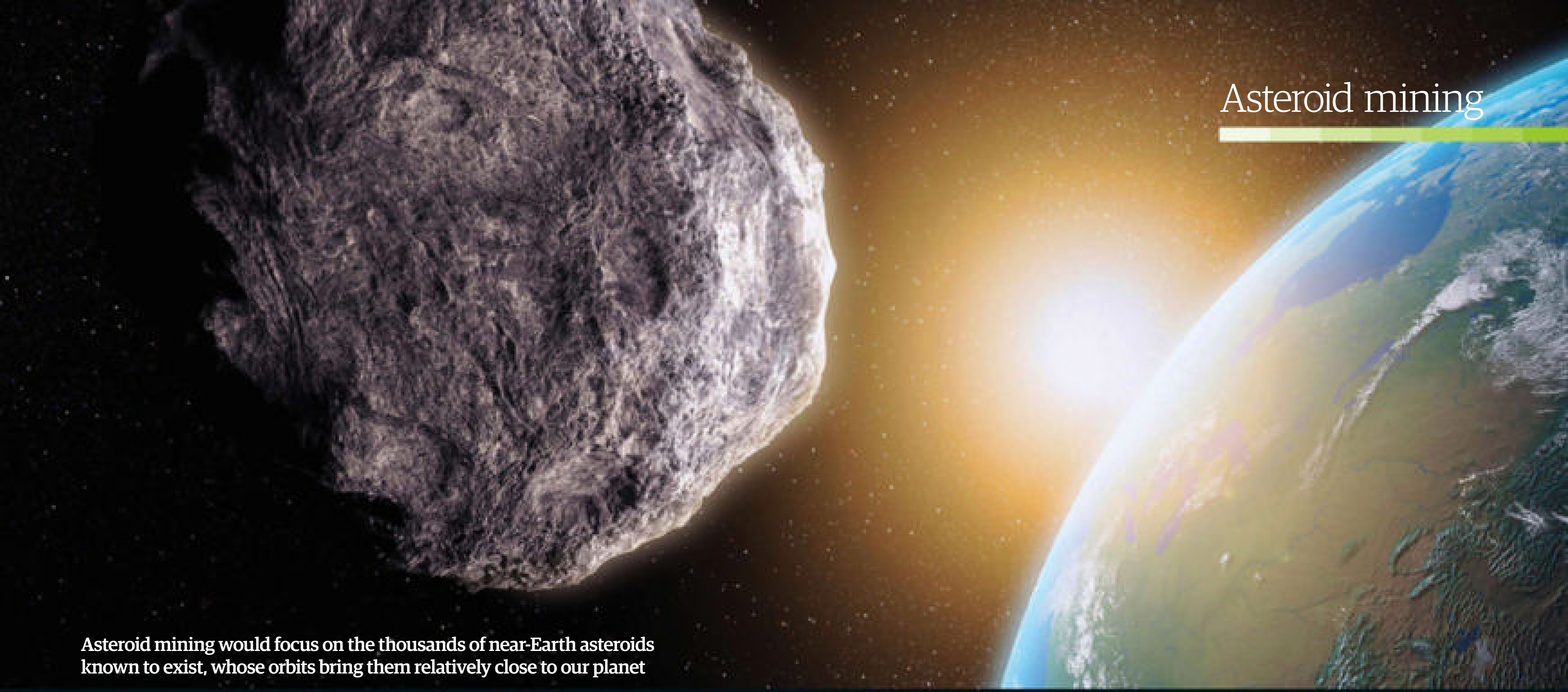


NASA astronauts training underwater for a potential future manned asteroid mission

Asteroid mining is no doubt a hugely challenging and ambitious endeavour that is not without its sceptics. And it's likely that, until we see actual operations begin, those critics will continue to air their views that these missions cannot be successful. But for all the hurdles and potential pitfalls, there must be a reason so many scientists, engineers and experts around the world are getting involved with the asteroid mining industry; they truly believe it can be done. And if some of the smartest minds in the world, who have landed spacecraft on other worlds in our Solar System and have extensively studied asteroids, hold the belief that asteroid mining is not only possible but it is also achievable in the immediate future, then there must be some method behind the madness.

"I do think asteroid mining will happen in the next 10 to 20 years," declares Notkin. "If, as we believe, these asteroids are rich in raw materials, I'm certain that we will see commercial mining in action. That's why I'm part of it. I wanted to be there at the beginning. I didn't want to look back in ten years and say 'oh no, I missed the boat on this.' To me this is the most exciting offer on the table, and I've leapt at the opportunity to be part of it."

To truly ascertain the progress that is being made towards asteroid mining, we will have to wait until next year when Planetary Resources and DSI begin launching their prospecting telescopes. If all goes to plan, and their confidence is rewarded with metal and water-rich asteroids, then asteroid mining could well become one of the major space industries of this century. With low-Earth orbit already well on the way to being commercialised with companies like SpaceX and Orbital Sciences getting involved, it will be an exciting time indeed if regions further into space are one day traversed by private companies returning resources from asteroids not only for use on Earth, but for creating and refuelling new spacecraft to explore regions of deep space like never before.



Asteroid mining would focus on the thousands of near-Earth asteroids known to exist, whose orbits bring them relatively close to our planet

Planetary Resources Chief Engineer

We talked to Chris Lewicki, also president of Planetary Resources, about its plans to create a new space industry

How did you get involved with Planetary Resources?

I'm an aerospace engineer and I spent the first ten years of my career working for NASA's Jet Propulsion Laboratory. I was the flight director when we landed the Spirit and Opportunity rovers on Mars and I was the mission manager for the Phoenix lander in 2008. And right around the time when we were finishing up that mission my old friends Eric Anderson and Peter Diamandis talked to me about the company they were starting, Planetary Resources. I thought the world was ready for this idea, and was very excited about getting involved.

Why is asteroid mining so important?

The mission of the company is to expand the economic sphere of influence off the surface of the planet and into the Solar System. Our space exploration for the last 50 years has been primarily government activities in exploration and science, and maybe even at the start in politics in terms of the space race. And that's not really sustainable in the long term. We see near-Earth asteroids as being key to unlocking the Solar System and helping to have a permanent human presence in space.

What resources are most important?

Asteroids have a wide variety of resources, from materials that can be used in fuel to precious metals. So that is a long-term interest. In the near term the first resource that will be available for use in space is water. Water is the essence of life, it is important for humans and plants to support us, but in space it takes on another dimension in that it can be used to shield us from radiation.

Why is water so useful?

A metre of water has as much protective power as the entire atmosphere does on Earth. Water is present on carbonaceous asteroids and in some cases it as much as 20% of their weight, and this water may exist as just frozen water from ice. And also you can take the molecules of water, the H2O, and break it into hydrogen and oxygen, and then you have the most efficient chemical propulsion fuel that is theoretically possible, the same fuel that launched all the Space Shuttles into space.

What do you work on day-to-day?

All mining starts with prospecting and learning more about the resources that are out there. We have a very experienced spacecraft development team here in Bellevue [Washington, USA] of about 40 engineers, many of whom like me have spent parts of their careers working with NASA. And today we're working on the prospecting technology, the robotic geologists that we will send out to the asteroids to do this prospecting.

How have other asteroid exploration missions helped?

Hayabusa was a relatively low-cost mission done by the Japanese space agency to the smallest asteroid we've yet visited, 25143 Itokawa, and even though they only brought back a tiny sample it was enough to understand the formation history of Itokawa. The Japanese have another mission in the works with Hayabusa 2 and the USA has its OSIRIS-Rex mission [in 2016], and these missions have really laid the groundwork for companies like ours to be able to use that information and take it further.

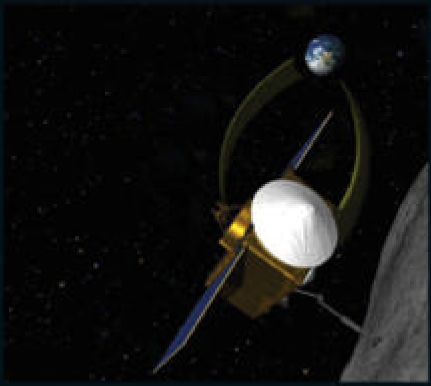
Missions like OSIRIS-Rex are quite expensive, how will you lower the costs of asteroid mining?

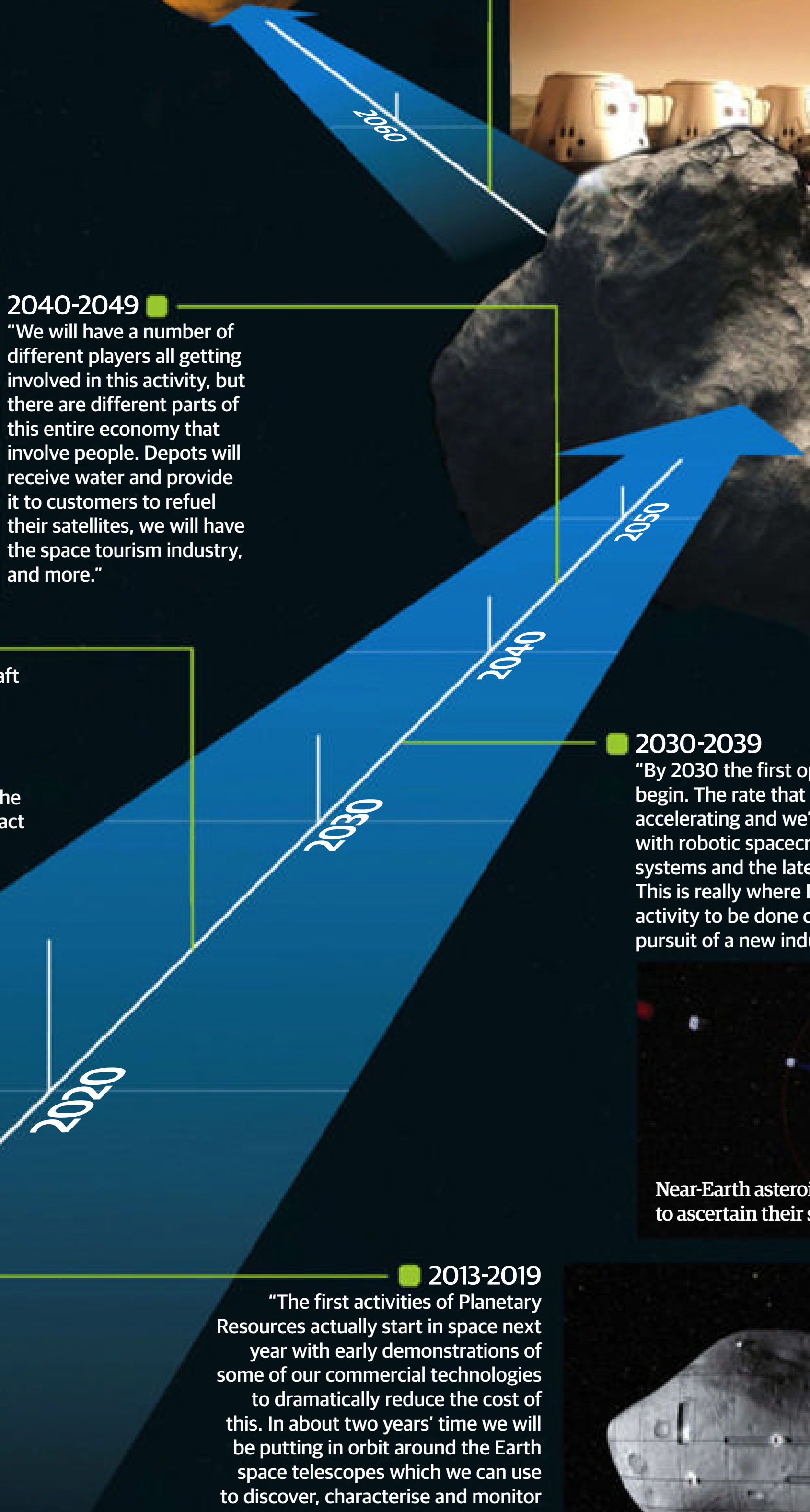
OSIRIS-Rex is a billion dollar mission. It's got a very large team, and it's got a very intricate and complex science mission. That drives the cost up. When we look at this from a commercial standpoint we can do things for prospecting an asteroid and learning about the resources that in the early days don't require bringing a sample back, which is very expensive. And additionally we see the possibility to do these missions with substantially fewer people. We actually think that within the next ten years we'll be able to send missions out to asteroids for as cheap as just a few million dollars each.

> "Near-Earth asteroids are key to having a permanent human presence in space"

Road to mining asteroids

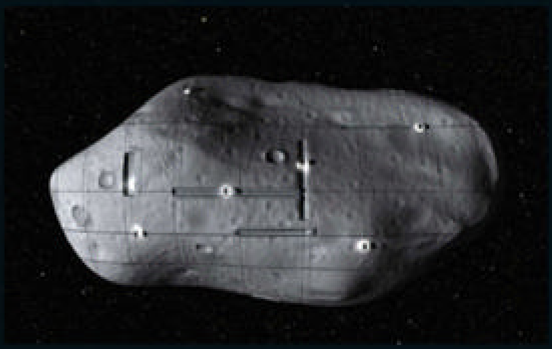
Planetary Resource's Chris Lewicki on what we can expect to see in the future





2013-2019

"The first activities of Planetary Resources actually start in space next year with early demonstrations of some of our commercial technologies to dramatically reduce the cost of this. In about two years' time we will be putting in orbit around the Earth space telescopes which we can use to discover, characterise and monitor potential asteroid targets that we will then go out and explore in more detail up close."



2020-2029

"By 2020 I really see us having several spacecraft missions out to a number of targeted asteroids of interest. Some of these are asteroids that are already known today, we have a top 20 list of favourites that we have. Within the first few years of the 2020s we'll be touching down on the surface of the first asteroid and starting to extract the first small amounts of water from some of these asteroids."

2030-2039

"By 2030 the first operations on asteroids will begin. The rate that technology is advancing is itself accelerating and we're doing all of our exploration with robotic spacecraft using highly autonomous systems and the latest in remote sensing capability. This is really where I see the opportunity for this activity to be done commercially, privately and in pursuit of a new industry like space resources."

Near-Earth asteroids will be studied in detail to ascertain their suitability for mining

2040-2049

"We will have a number of different players all getting involved in this activity, but there are different parts of this entire economy that involve people. Depots will receive water and provide it to customers to refuel their satellites, we will have the space tourism industry, and more."

2050-2059

"I think by 2050 we'll be well beyond just finding asteroids. We'll be on the surface of the Moon, we'll have colonies and habitats on the surface of Mars, and we'll really be able not only to develop resources of the asteroids but resources of the rest of space and we'll look back through in time just as we do with aviation today and wonder how the world got along before that happened."

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The Moon

The most visible celestial object from Earth has been the source of human fascination for millennia, yet we're still discovering more about it all the time

Orbiting at a distance of anywhere between 362,570 kilometres and 405,410 kilometres (225,000 to 252,000 miles) and moving away from the Earth at almost four centimetres (1.57 inches) per year, all 74 billion trillion kilograms (160 billion trillion pounds) of blasted grey rock that is the Moon never fails to make for fascinating viewing. Its topography is a pattern of 'maria' – impact basins once filled with lava – and giant craters that are clearly visible from Earth.

Most notable of these is Tycho on the near side of the Moon. Despite being around 86 kilometres (53 miles) in diameter and 4.8 kilometres (three miles) deep, it's not the largest of the Moon's impact features: that accolade goes to the South Pole-Aitken basin on the far side, which is 2,500 kilometres (1,550 miles) in diameter, 13 kilometres (eight miles) deep and one of the biggest craters in the Solar System. But with its distinctive ray system fanning out for hundreds of kilometres across the surface in all directions, Tycho is the Moon's most recognisable feature.

We're still learning about the Moon, the most recent major mission being the Gravity Recovery and Interior Laboratory (GRAIL) mission that generated the highest resolution gravity map of any celestial body. ■

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Josh Barker

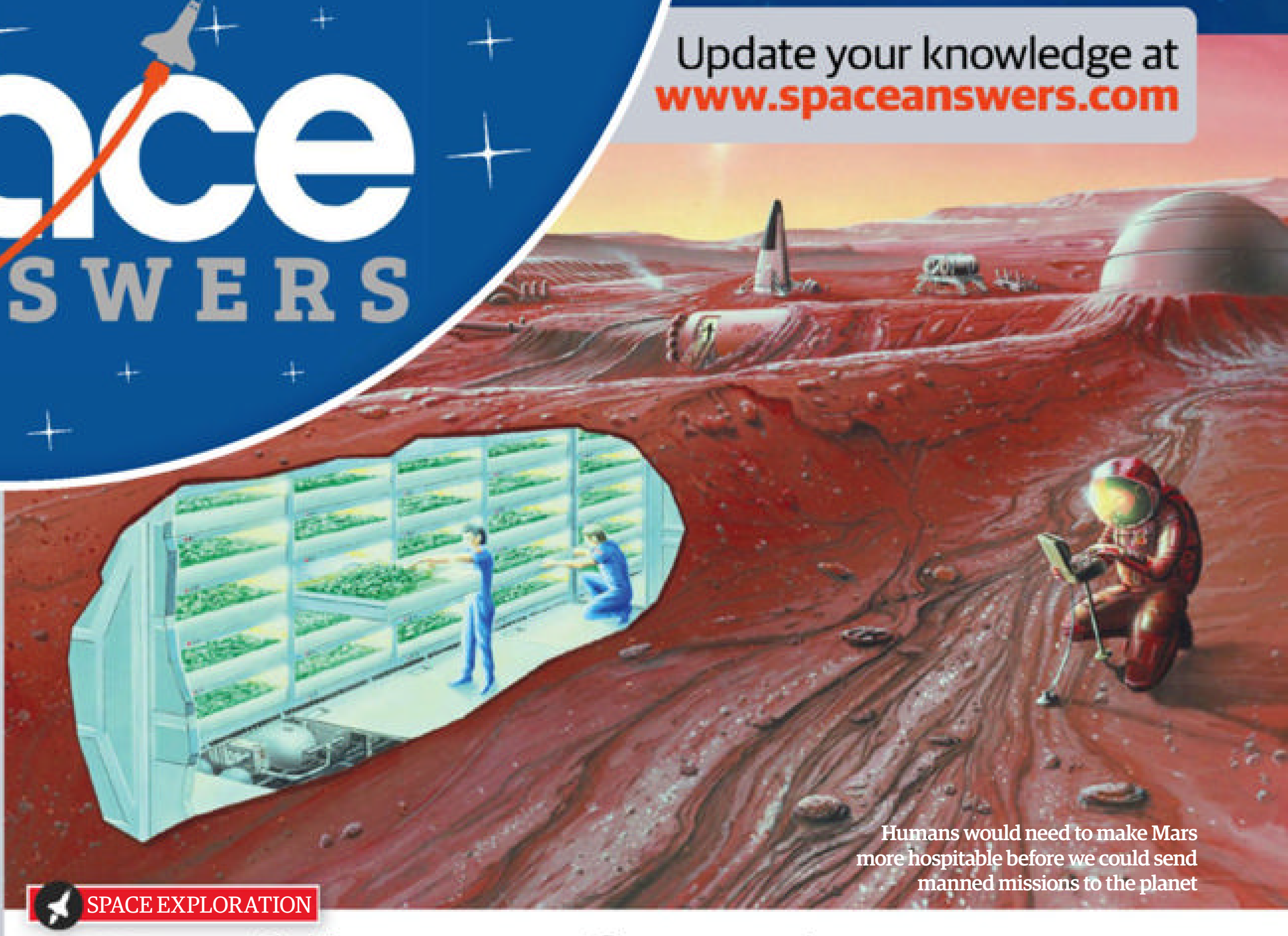
Education Team Presenter
■ Having achieved a Master's in Physics and Astrophysics, Josh continues to pursue his interests in space at the National Space Centre.

Gemma Lavender

Science journalist
■ Gemma holds a degree in Astrophysics and has worked as a science journalist for three years. She was recently elected as a fellow of the Royal Astronomical Society.

Jonathan O'Callaghan

Senior Staff Writer
■ Jonathan read Physics and Astrophysics before becoming a writer on our sister publication **How It Works**, where he specialised in space science and exploration.



Humans would need to make Mars more hospitable before we could send manned missions to the planet

SPACE EXPLORATION

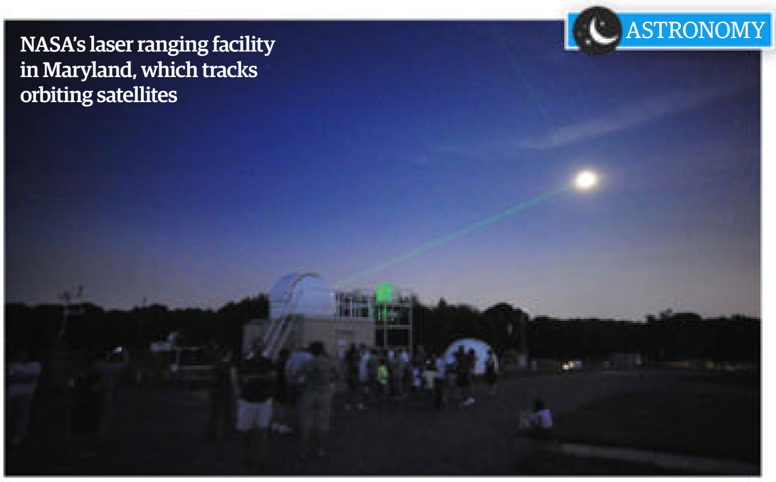
Would terraforming Mars affect its gravity?

Chris Howlet

No, gravity is influenced very much by the mass of the object in question. This means that, in order for the gravity of Mars to be affected, we would somehow have to either add mass to the Red Planet or take it away. Terraforming Mars – that's making it more hospitable for human habitation – does neither of these things.

Instead, terraforming Mars involves the incredible feat of building up its atmosphere, keeping the globe warm and keeping that atmosphere from being lost to outer space. Mars's gravity (which is 38% that of Earth's) combined with its questionable magnetic field means that, throughout its history, its atmosphere has been stripped away by the solar wind. Now, a thin layer of mostly carbon dioxide, that makes Mars quite unfriendly for humans, covers the planet. And, with no way of adding mass to the planet to increase its gravity for a much-needed atmosphere to be sustained, we would need to resort to another plan – we would have to bring gases and other materials to Mars ourselves.

Importing gases such as ammonia, hydrogen and organic materials from other celestial bodies would be the way to go as well as sublimating the ice at the Martian south pole to a gas, releasing the carbon dioxide trapped within it, which would, in turn, increase the atmospheric pressure. Plants could also be brought to the surface to create oxygen for us to breathe. **GL**



NASA's laser ranging facility in Maryland, which tracks orbiting satellites

ASTRONOMY

How does a telescope red-dot viewfinder work?

Thomas Ellis

'Red-dot' viewfinders come in two varieties. One uses a laser sight to find objects in the night sky. This system works by firing a laser on to the target so that it can be picked up by a viewer, although sometimes these lasers aren't in the visible spectrum and so special filters are placed in the viewfinder to reveal the laser. The other type uses a semi-silvered mirror to reflect an LED in the telescope's viewfinder into the observer's line of sight. In the viewfinder a red-light LED will shine, this is then reflected and collimated to appear in the finder itself. These sights can help to pinpoint targets when observing objects.

However, as a general rule red-dot sights are not found on telescopes as they can make viewing night-sky objects more difficult. **JB**

Make contact: @spaceanswers /AllAboutSpaceMagazine questions@spaceanswers.com

Spiral galaxies merging in the Virgo constellation

DEEP SPACE

What happens when galaxies collide?

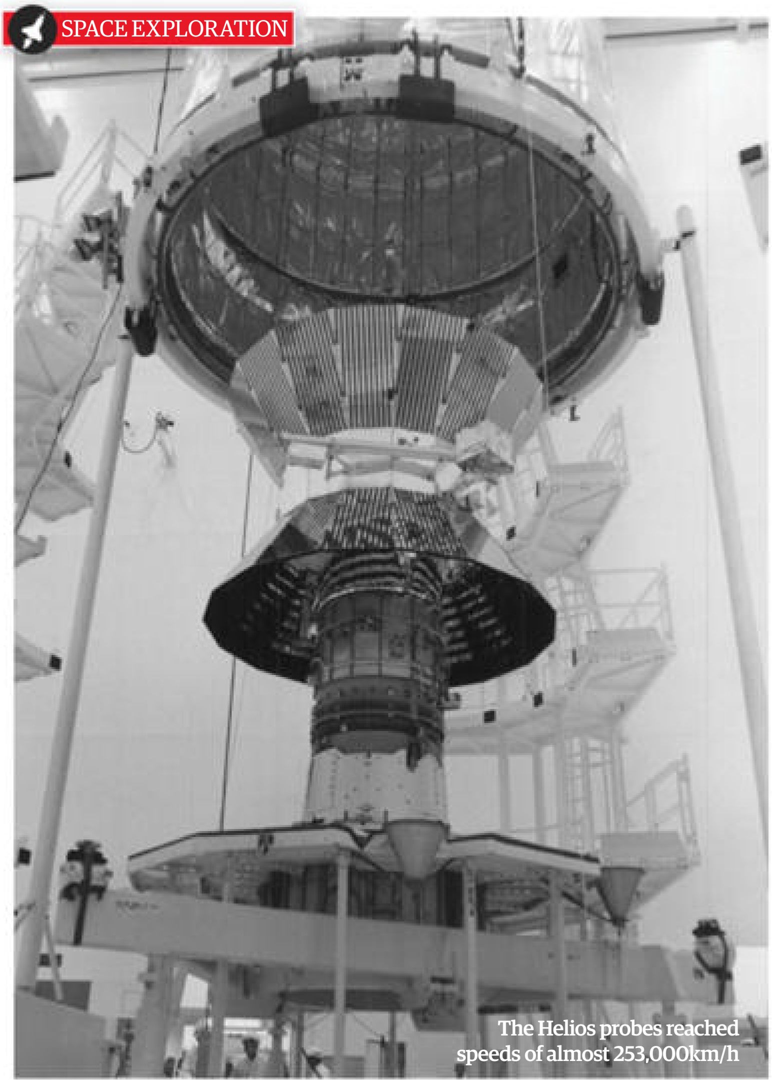
Drew Wells

'Merge' might be a clearer way to explain what happens when two galaxies interact. When we think of collisions we imagine two or more things smashing together, this usually results in things breaking and there generally being a mess. This makes the prospect of a galaxy filled with billions of giant burning balls of highly volatile gas quite an exciting one.

Unfortunately, this isn't the case and this is all to do with the spacing of stars. Galaxies are teeming with billions of stars, but they are also very, very large. This means these stars are spread out - very spread out. To give you an idea of just how spread out, the average particle in air is 500 times its own width from another particle. Our Sun is 29 million times its own width from the next nearest star.

So when galaxies collide we don't see Hollywood-style explosions; in fact, close up you probably wouldn't notice much. The collisions are so tame that they are usually just referred to as 'mergers'. This is also to do with the fact that galaxies that have collided have a tendency to stick together. Because of the huge amount of stuff in a galaxy they have a strong gravitational influence. This can cause them to interact with each other as they get close together. In mergers we see galaxies pull and twist each other, stretching out huge bulks of material. This can change the structure of galaxies, destroying things like spiral arms, resulting in more globular types. **JB**

SPACE EXPLORATION



The Helios probes reached speeds of almost 253,000km/h

How did the Helios probes travel so fast?

Ross Hartley

The Helios probes hold the esteemed title of being the fastest satellites in space. They reached almost 253,000km/h (158,000mph) as they raced around the Sun measuring the solar wind and the environment near to the Sun.

The main reason the Helios probes were travelling so fast is because their trajectory had them plummet towards the Sun. The Sun is the dominant source of gravity in our Solar System, holding all the planets, asteroids and other bits in orbit. The gravitational force of our local star is incredibly strong and the force increases as you get closer to the source.

As the Helios probes got closer to the centre of our Solar System their gravitational attraction to the Sun would have increased causing them to accelerate more.

The designs and missions of these probes meant that they passed fairly close to the Sun which is why they were able to reach such high speeds.

Interestingly, due to orbital mechanics, when the spacecraft left Earth they had to slow down. This reduction in speed caused the craft to start falling towards the Sun. **JB**

SOLAR SYSTEM

Why do meteorites create such huge craters?

Laura Easton

Solid pieces of debris that have broken off from asteroids or comets, called meteorites, often create impact craters on the surface of terrestrial planets and moons. These craters are caused on Earth because, when these chunks of rock pass through the atmosphere, they are too large to be slowed down and smash into the surface at a velocity of around 12 to 20 km/sec (7.5 to 12.5 miles/sec).

Two types of crater are often made by debris that crashes through the Earth's atmosphere - some are bowl-shaped, whereas others are of a similar appearance but contain a raised central peak along with a risen rim which appears as a ring-shaped structure from a bird's-eye view. However, a meteorite doesn't have to be large to make a great impact - the Barringer Crater in Arizona, which has a diameter of just over a kilometre (0.6mi) across was made by a chunk of space rock about 50m (160ft) in diameter. It is the speed of these pieces of rock that determine the crater's size. But that's not all.

The angle at which a meteorite impacts the ground as well as the type of material it smashes into are also important factors. By studying impact craters, planetary scientists are able to piece together how the crater happened. In fact, simulations have been made that investigate such a scenario - LCOGT and Faulkes Telescope's Impact Simulator (http://simulator.down2earth.eu/) or Purdue University's Impact Earth (www.purdue.edu/impactearth/) are such examples. Give them a try. **GL**

The Barringer Crater in Arizona, USA is just over 1km in diameter

SOLAR SYSTEM

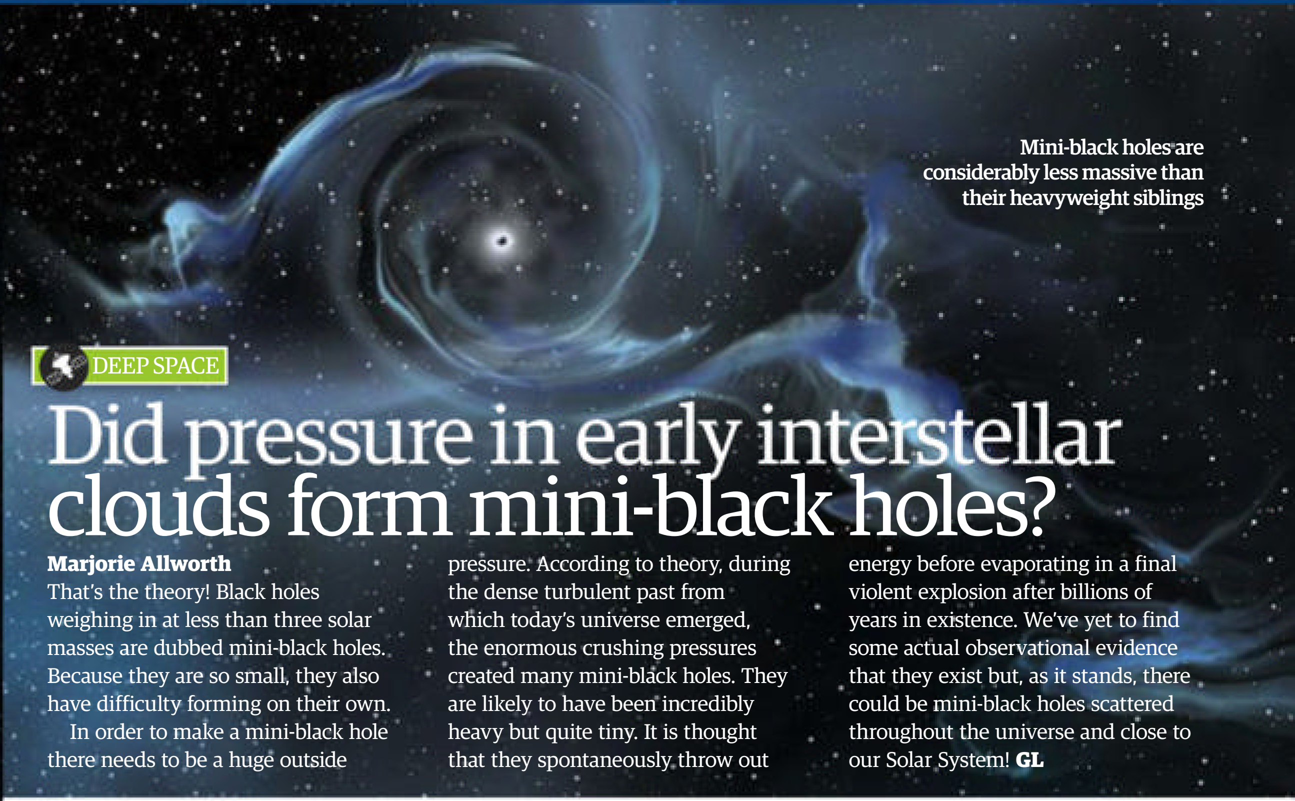
Why haven't humans visited any other planets?

Sarah Andrews

Technically, we haven't had any manned missions to any planets yet. The outer planets, with their high pressures and gaseous compositions that lack a solid surface are unlikely to be entered by humans. Meanwhile the inner planets are, in general, too hostile for us to land on due to their proximity to the Sun - Mercury and Venus are too hot and the pressure on Venus much too high. Only Mars seems to be really within reach and, as a result, this planet has been chosen as something of a happy medium.

Information gathered by previous and current missions has shown Mars to have similar characteristics to our planet. These similarities make Mars the most logical next step when it comes to exploring other worlds. Not only do we think it is feasible to send humans on a flyby mission, but one day we could even walk on Mars's surface.

Mars is also close to Earth, meaning that astronauts would have to travel no more than 150 to 300 days depending on the speed of launch and alignment of Earth and Mars, making the journey a bit of a safer choice. Of course, even travelling to, let alone landing on, Mars, will prove costly. So imagine just how much more expensive and dangerous going to other planets would be - mankind is not ready for that just yet! **GL**



Mini-black holes are considerably less massive than their heavyweight siblings

DEEP SPACE

Did pressure in early interstellar clouds form mini-black holes?

Marjorie Allworth

That's the theory! Black holes weighing in at less than three solar masses are dubbed mini-black holes. Because they are so small, they also have difficulty forming on their own.

In order to make a mini-black hole there needs to be a huge outside pressure. According to theory, during the dense turbulent past from which today's universe emerged, the enormous crushing pressures created many mini-black holes. They are likely to have been incredibly heavy but quite tiny. It is thought that they spontaneously throw out energy before evaporating in a final violent explosion after billions of years in existence. We've yet to find some actual observational evidence that they exist but, as it stands, there could be mini-black holes scattered throughout the universe and close to our Solar System! **GL**

One way to visualise the expanding universe is to compare space with the surface of an expanding balloon

DEEP SPACE

If the universe is finite, what would we be able to see at the 'edge'?

Sophie Roberts

We don't know. This is actually one of the 'big questions' currently being discussed in the field of space science. This particular mystery is one that has many questions surrounding it, possibly the most relevant being, 'is the universe finite?' There is still no universally agreed answer to that question. One camp believes that it must be but others disagree. It is possible to see a sphere around the Earth of around 46.5 billion light years from middle to edge. This makes up the observable universe but is unlikely to be the full extent of space, this is just the visible part.

Even if we agree that the universe is finite and has an edge, what is at the edge is another topic up for debate. One of the strongest theories for the geometry of the universe is that it is like a giant expanding balloon. The effect of this geometry is that looking far enough in any particular direction will cause the same thing to be seen. **GL**

DEEP SPACE

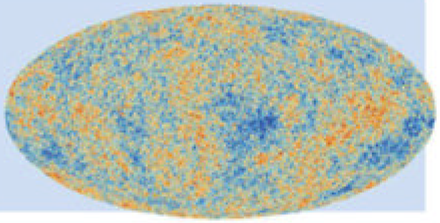
What is ‘heat death’?

Moe Webster

‘Heat death’ - also known as the ‘big freeze’ or the ‘big chill’ - has been suggested as one of the ways in which the cosmos could come to an end.

The idea of heat death actually originates from the second law of thermodynamics - that’s the idea that entropy increases in an isolated system (such as the universe). Entropy, which is the number of ways in which a system can be arranged, should never decrease, evolving to a state of maximum disorder (or thermodynamic equilibrium). When this happens, all energy will be evenly distributed throughout the cosmos, leaving no room for any reusable energy or heat to burst into existence. Processes that consume energy, which includes our very living on Earth, would cease. You might think that heat death implies some astronomically high temperature. However, it has been suggested that the more the universe expands, the cooler it gets.

We’re looking at a continual expansion of the universe, according to readings of the Cosmic Microwave Background, but at a decreasing rate and it looks likely that the cosmos will end in a heat death. **GL**



SPACE EXPLORATION

How long can astronauts live in space for?

Adam Jones

We don’t know exactly, although astronauts on the ISS will typically spend anywhere up to six months in space. However, the record for the longest single spaceflight is currently 437.7 days, held by Russian astronaut Valeri Polyakov.

No one has tried living in space for longer than that, though, and the effects of living in weightlessness for longer periods is currently unknown as it has never been attempted. What we do know, however, is that the time astronauts spend in space does have some effect on the human body and regular exercise helps to combat the otherwise negative impacts of the loss of muscle and bone density. **GL**

SOLAR SYSTEM

Why was Pluto downgraded to a ‘dwarf planet’?

Matt Francis

Many people will remember the controversy generated back in 2006 when the reclassification of Pluto took place. Pluto’s place as a planet at this point had been questioned since the Seventies. Other objects had been found in the Solar System of a comparable size and these objects weren’t classified as planets.

In August 2006, the International Astronomical Union (IAU) met and redefined exactly what ‘planet’ meant. It was decided that Pluto did not fit within that definition and so it was added to the new classification of dwarf planet. To qualify as a planet an object must orbit the Sun, have sufficient mass to become roughly spherical and to have ‘cleared the neighbourhood’ around its orbit. Pluto passes the first two criteria but because it crosses the orbit of Neptune it is not deemed to have cleared its neighbourhood.

Pluto is not alone in the dwarf planet category, joining four others. Of these five objects, Pluto is only the second largest with Eris just beating it to the top spot. For a few months after its discovery in 2005 Eris was referred to as the tenth planet of the Solar System, however, this moniker was promptly dropped after the IAU meeting in 2006. **JB**

Quick-fire questions

@spaceanswers

How many galaxies are there in the universe?

It is difficult to put an exact number on it. However, thanks to powerful instruments such as the Hubble Space Telescope, it is currently estimated that there are approximately 100 billion galaxies in the universe.

Does everything have gravity?

If it has mass, then it certainly has gravity. That includes yourself, the planets, our galaxy, and even the copy of **All About Space** that you’re holding right now.

How many spacecraft have travelled beyond the asteroid belt?

In total nine spacecraft have travelled past the asteroid belt - Pioneer 10, Pioneer 11, Voyager 1, Voyager 2, Ulysses, Galileo, Cassini-Huygens, New Horizons and Rosetta.

How much of Jupiter is gas?

The vast majority of Jupiter is made up of gas - mainly hydrogen and helium along with traces of methane and ammonia. However, a liquid core could exist at its centre.

How many Earths fit into the Sun?

The Sun has a radius some 100 times that of the Earth meaning that around 1.3 million Earths fit into the Sun.

How much power does the Sun generate?

Our Sun releases around 386 billion million gigawatts of power into space. A large nuclear reactor, in comparison, generates about one gigawatt and Earth consumes about a few thousand gigawatts.

Does the Moon have a core?

It’s thought that the Moon does have a core and it is similar to our planet’s - a solid, iron-rich inner core with a fluid, primarily liquid-iron outer region.

Quick-fire questions

@spaceanswers

Why don't we see the other side of the Moon?
The Moon makes one revolution around the Earth about every 29 days. However, the Moon also rotates on its axis every 29 days, so we always see the same side.

What's the brightest known supernova?
One of the brightest recorded supernovas was the Crab Nebula in 1054. The most energetic is a bit more difficult to pin down as the energy of a supernova is not equal to its brightness!

How big will the Sun grow?
In around 5 billion years, as the Sun uses up its nuclear fuel and turns into a red giant its radius will swallow up Mercury, Venus and Earth, possibly expanding as far as the orbit of Mars.

How hot is Mercury?
Mercury's tight orbit ensures the side facing the Sun bakes to a sizzling 430°C (806°F) while its far side shivers in -163°C (-261°F) temperatures. Despite its proximity to the Sun it's not the hottest planet: that accolade goes to Venus, whose atmosphere ensures the planet is a toasty 462°C (863°F).

Which is the smallest constellation?
That accolade goes to Crux, which is made up of four main stars. It's only visible from southern hemisphere locations or tropical latitudes in the northern hemisphere for a few hours at certain times of year.

Which is the largest constellation?
Hydra consists of 17 primary stars and is also the longest constellation, spanning approximately 1,300 square degrees of the sky.

SPACE EXPLORATION

If space is so cold, why did the Herschel Space Observatory need cooling?

Philip Payne

For a number of reasons, one of which is that space still isn't cold enough. Certain satellites often need cooling in space to work properly, the Herschel Space Observatory is a prime example of this. This telescope detects infrared radiation. This type of radiation is associated with heat so any sources of heat can be detected.

It is often said that space is very cold and this means that the concept of needing to cool something in space seems bizarre. The issue originates from two main reasons. The first is that space is practically empty so as heat radiation travels it doesn't disperse much and heats the first thing it comes into contact with. This is how the Sun can warm up the Earth despite being such a long way away. Satellites that need to be cooled counteract this by using a sunshield, this can block the infrared radiation reaching the sensitive instruments.

The other problem is the electronics on board. Much of the circuitry on board generates heat, so the satellite will slowly warm itself up during operation. If the lenses and sensors of a telescope are warm they create a lot of interference and noise when trying to detect faint signals. To prevent this, many satellites are actively cooled, this keeps the equipment cool enough that it generates minimal infrared radiation. This ensures the maximum impact from any telescope. **JB**

ASTRONOMY

What is light pollution?

Dave Ridgley

Light pollution is excessive or misdirected artificial light. It comes from a number of sources, from streetlights to external lighting. The majority of light pollution comes from lights either being pointed upwards or the light bouncing off of objects and scattering into the sky. With the main sources being street lights and illuminated buildings it is obvious that light pollution is considerably worse in heavily developed areas.

Excessive light pollution can have some notable effects, one being 'skyglow'. Skyglow is the name given to the phenomenon of a glow effect that is often seen over populated areas. This glow is caused by the badly directed light shining into the atmosphere then being scattered by the air back down towards the ground.

Light pollution, especially skyglow, is a major irritation to astronomers and other stargazers. This is because it reduces the contrast in the night sky. This contrast reduction makes it much more difficult to see and image stars. Strong light pollution often limits which objects can be seen, with observers only being able to make out the very brightest stars in densely populated areas.

To escape light pollution telescopes are often built far away from populated areas, minimising light pollution and maximising their ability to see the night sky. **JB**

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An image of the Hubble Ultra Deep Field: if the universe is doughnut-shaped, we might be able to see ourselves

ASTRONOMY

Is the universe a loop?

Aaron Hardy

Cosmologists have given serious thought as to whether our universe is curved rather than flat. In a flat universe, two parallel lines running next to each other will never meet. That seems sensible, but were we to draw two parallel lines on Earth they would eventually coincide at the poles. That is because the Earth is curved.

If the universe were looped, like a doughnut, then in theory if you travelled far enough you would loop around and end up where you began. Light would also do the same thing, so in theory, if the universe were small enough, a big enough telescope would be able to see itself. The light wouldn't just stop there either, but go around and around like a hall of mirrors.

Astronomers have tested for this effect, searching for patterns of galaxies in the sky that appear to be the same, but have found no evidence for this. That could mean that the universe is not curved at all. Or, it could mean that it is curved, but on scales so large that we cannot see: the expansion of the universe means that there are galaxies we'll never see beyond our cosmic horizon, as light will not have enough time to travel that distance. If the universe is curved at scales larger than this cosmic horizon, light would never have time to loop back on itself. **GL**

SOLAR SYSTEM

What would happen if the Earth had two moons?

Matt Francis

Our Moon's gravitational tug is a key player in the creation of our ocean's tides and is the reason our day is 24 hours long. It also keeps our planet's axis tilted at the same angle supplying us with the four seasons.

If a second moon were to be in orbit around the Earth, things would be quite different; the calm tranquil planet that we know would be thrown into chaos with a greater tug of gravity causing massive earthquakes, increased volcanic activity and gigantic tsunamis. Ash and chemicals spewing from volcanoes would rain down killing everything on Earth. We would also need to adapt to high tides as the habitable area of Earth would shrink and our months would be irrelevant with full and partial months needed to be put into place to account for the movement of two moons. **GL**

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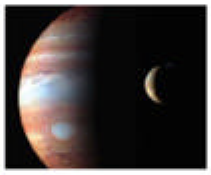
Next Issue

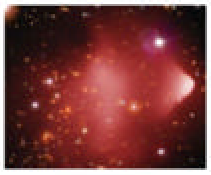
MEGA ROCKETS

The super-powerful rockets that can take us to the Moon, Mars and beyond



GIANT UNIVERSE

From giant stars to supergalaxies, we look at the ten biggest things in the universe



ANTIMATTER

What is antimatter and what role does it play in the universe? We investigate next month

ALL ABOUT EUROPA

The sixth moon from Jupiter that could be an icy harbour for extraterrestrial life

+

SPACE FOG
MESSIER-42
SPACE FARMING
CURIOSITY: ONE YEAR ON
THE INFRARED UNIVERSE
THE JAMES WEBB SPACE TELESCOPE

In orbit
25 July 2013

STARGAZER

GUIDES AND ADVICE TO GET STARTED IN AMATEUR ASTRONOMY

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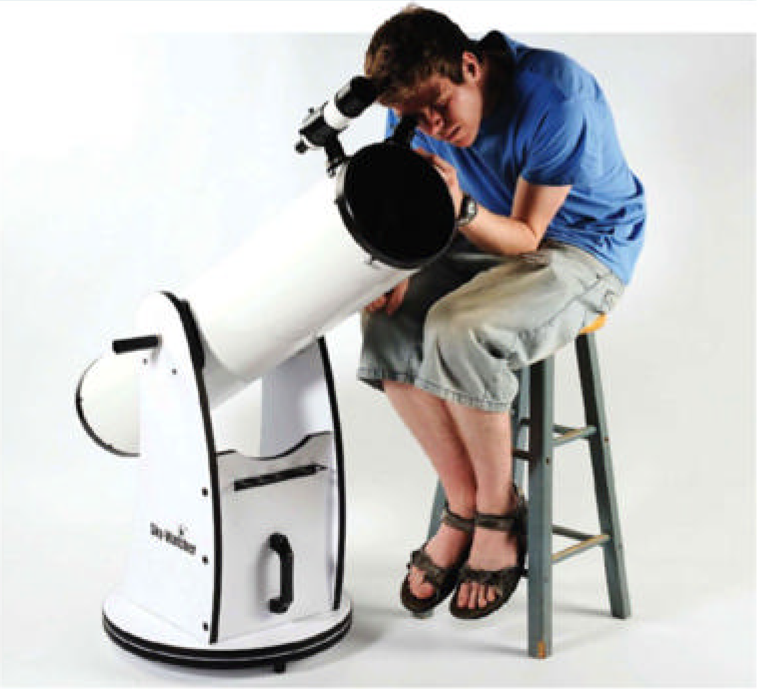
All About... Dobsonian telescopes

There is a lot of misunderstanding about Dobsonian telescopes; what they are and what they can do. This should help clear it up...



The Dobsonian telescope is a Newtonian reflecting telescope on an altazimuth mount. It is the mount that distinguishes it from any other type of Newtonian reflector and this was popularised in the Sixties by avid amateur astronomer John Dobson. It's thought that Dobson invented the design for the mount, but as he freely admitted, the idea had been around for many centuries as cannons were mounted in such a way and wars fought using them. However, he developed the idea that Newtonian reflectors could be mounted on a simple platform using household parts and therefore very cheaply, and so his name was attached to the now ubiquitous amateur telescope.

It is their simplicity of design and cheap parts that made these telescopes so popular. There were many differing variations on the theme, some being very sophisticated and rather getting away from the humble and inexpensive materials and design. The popularity was quickly appreciated by commercial telescope manufacturers and so you can find Dobsonians as mass-produced products of varying size and quality, as well as in kit form.

Dobsonians are often known as 'light buckets' as they are an inexpensive way of owning a relatively large aperture telescope - most of the money you spend is put into the optics rather than the mount. In other words, the amount you pay for say a ten-inch aperture Dobsonian may only buy you a six-inch Newtonian on an equatorial mount. One of the advantages of the Dobsonian therefore, is the 'bang for your buck' in terms of aperture. When homemade, they are often built from plywood and other lightweight yet stable materials and usually disassemble easily for transportation and storage. Indeed, it is possible to have a 16-inch aperture telescope that fits into the back of a small family car. This means you can travel to a dark sky site and take advantage of it with a large telescope. They are, however, not suitable for some forms of observing.

Because the user has to constantly move the telescope to follow objects, observing anything at more than moderate magnifications can be awkward. Teflon bearings are used to give frictionless movement but there is still the inertia of the telescope to overcome. Dobsonians are not very suitable for anything other than basic astrophotography due to being on an altazimuth mount rather than equatorial. It is possible to get motor drives and 'goto' systems for 'Dobs' nowadays and even equatorial platforms, but this rather goes against the original idea of the Dobsonian telescope as being a cheap alternative for avid amateur astronomers.

The appeal of the Dobsonian telescope is unlikely to diminish any time soon, though, as they make a great introductory telescope for beginners and are ideal for experienced observers on a budget.

Jargon Buster

Altazimuth

An 'altazimuth' mount is where the telescope can move in altitude, in other words up and down, as well as azimuth, or around a vertical axis in circles. Although it's a long name the altazimuth mount is the simplest of telescope mounts. A camera tripod is a form of altazimuth mount.

Mirror box

The mirror box on a Dobsonian telescope is, unsurprisingly, the part that houses the main mirror of the telescope. It is often made from plywood and acts as the support for the main mirror as well as being the interface for the telescope tube which holds the secondary mirror, spider and focuser.

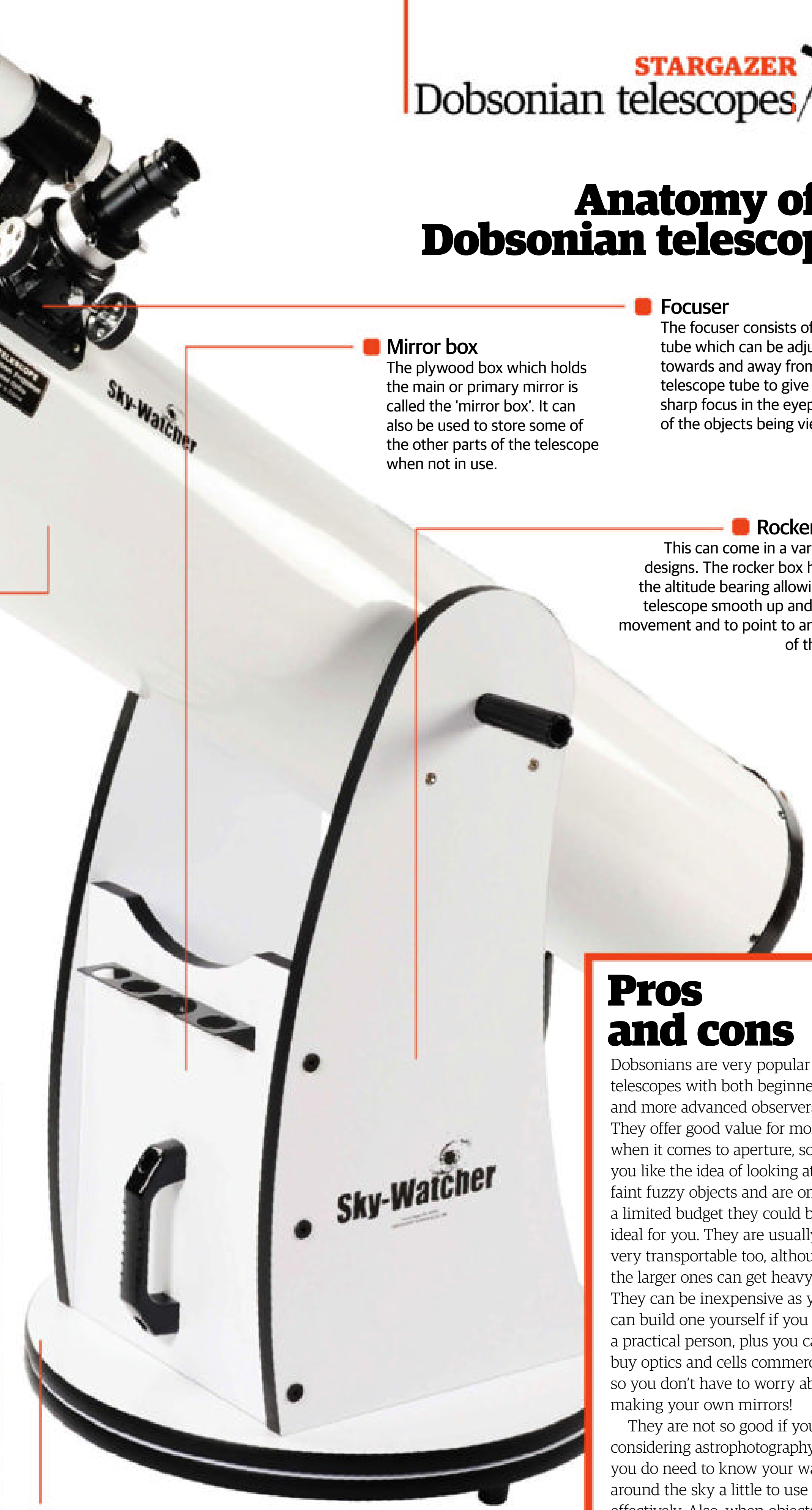
Telescope tube

These were originally made from compressed paper similar to those used in the construction industry for producing concrete pillars. They are cheap and practical and can be bought in a number of diameters. They are easy to work and stable and ideal in many ways for amateur Dobsonian telescope building.

Rocker box

This is where the altitude bearing is found. Often made of plywood with the bearing surfaces lined with Teflon or other friction-free material. It is the pivot where the telescope 'rocks'. Designs vary enormously and can have small round or large 'half-moon'-shaped bearings in the larger and more advanced models.

Anatomy of a Dobsonian telescope



Focuser
The focuser consists of a tube which can be adjusted towards and away from the telescope tube to give a sharp focus in the eyepiece of the objects being viewed.

Mirror box
The plywood box which holds the main or primary mirror is called the 'mirror box'. It can also be used to store some of the other parts of the telescope when not in use.

Rocker box
This can come in a variety of designs. The rocker box houses the altitude bearing allowing the telescope smooth up and down movement and to point to any part of the sky.

Tube
This can be made from 'construction tube', plywood or other suitable material. The tube holds the secondary mirror, the 'spider' support and the telescope's focuser and finder scope.

Azimuth bearing
The bottom bearing of the telescope is the azimuth bearing, which allows the telescope to rotate smoothly, often in the form of plywood or MDF discs with Teflon for friction-free movement.

> "Observing anything at more than moderate magnifications can become awkward"

Dobsonian telescopes are a cheap option but not ideal for astrophotography

Pros and cons

Dobsonians are very popular telescopes with both beginners and more advanced observers. They offer good value for money when it comes to aperture, so if you like the idea of looking at faint fuzzy objects and are on a limited budget they could be ideal for you. They are usually very transportable too, although the larger ones can get heavy. They can be inexpensive as you can build one yourself if you are a practical person, plus you can buy optics and cells commercially so you don't have to worry about making your own mirrors!

They are not so good if you are considering astrophotography and you do need to know your way around the sky a little to use them effectively. Also, when objects are near the horizon, you will need to bend over to view them, not so good if you have a bad back.

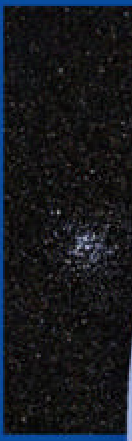
What's in the sky?

The summer offers some fantastic night-sky sights. Here are some of this month's must-sees

Open Cluster M11

Viewable time: All through the hours of darkness

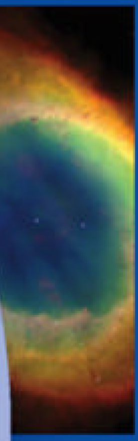
M11 is a lovely open cluster of stars sometimes known as the Wild Duck Cluster. Through binoculars the stars can indeed look like a formation of flying ducks. Through a telescope the stars appear compact, almost like a globular cluster. This is in fact one of the richest and most compact star clusters known. It contains approximately 2,900 stars and is thought to be 220 million years old. It lies in the constellation of Scutum the Shield.

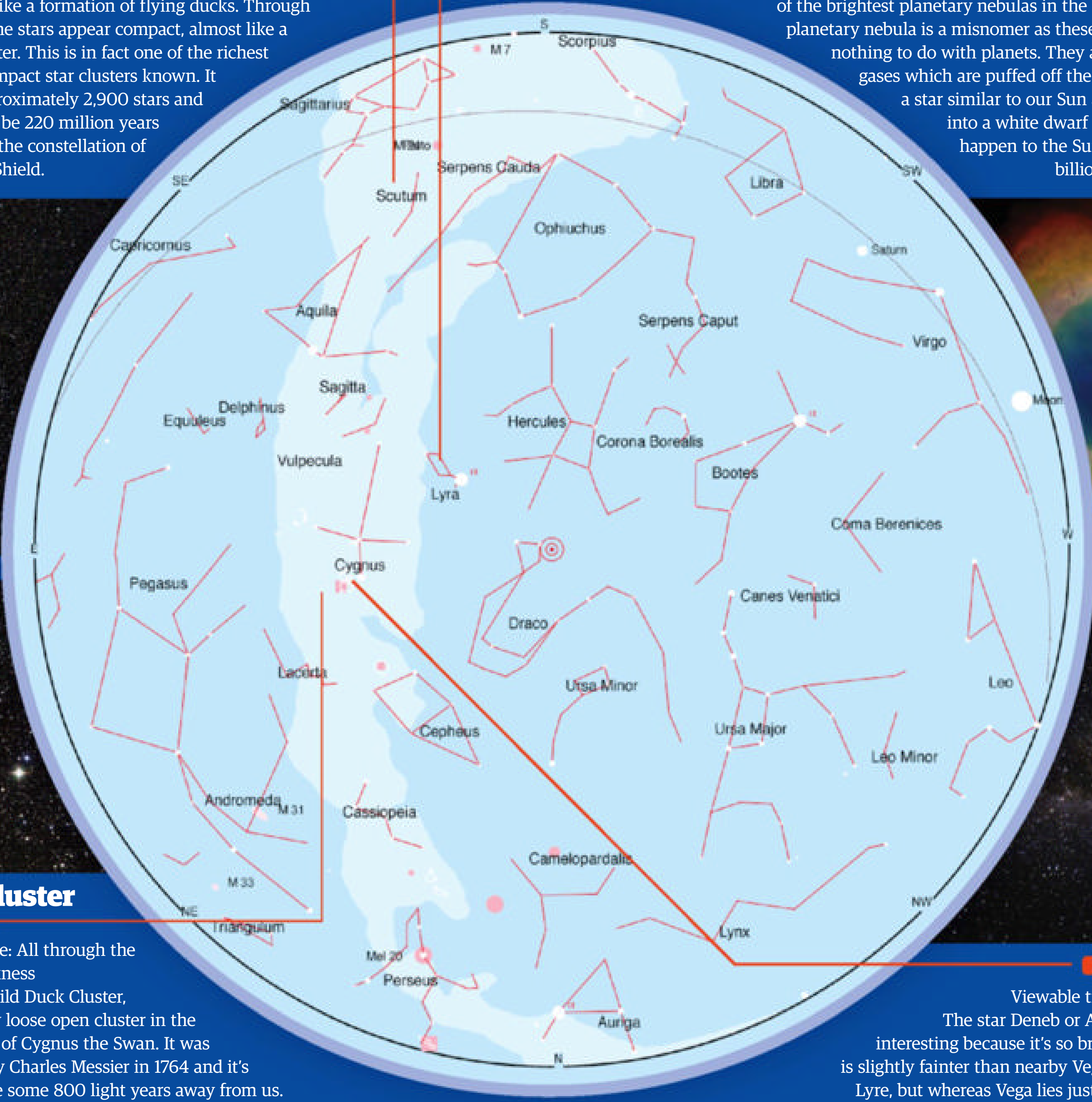


Planetary Nebula M57

Viewable time: All through the hours of darkness.

Otherwise known as the Ring Nebula for obvious reasons once you see it through a telescope, M57 is one of the brightest planetary nebulas in the sky. The term planetary nebula is a misnomer as these objects have nothing to do with planets. They are bubbles of gases which are puffed off the outer shell of a star similar to our Sun as it collapses into a white dwarf star. This will happen to the Sun in around 4 billion years' time.



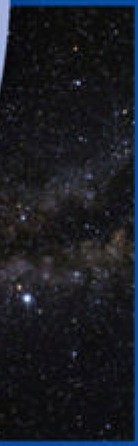


Northern hemisphere

Open Cluster M39

Viewable time: All through the hours of darkness

Unlike the Wild Duck Cluster, M39 is a very loose open cluster in the constellation of Cygnus the Swan. It was discovered by Charles Messier in 1764 and it's thought to be some 800 light years away from us. Its age is uncertain, probably being between 200 and 300 million years. Through a small telescope it looks like a collection of bright stars in the field of view of a low-power eyepiece. It shows up quite well in binoculars, too.



Deneb

Viewable time: All night

The star Deneb or Alpha Cygni is interesting because it's so bright. In fact it is slightly fainter than nearby Vega in Lyra the Lyre, but whereas Vega lies just over 25 light years from us, Deneb is around 2,600 light years away! So in order to appear almost as bright as Vega, it must be colossally bright. If Deneb was around 25 light years from us, it would drown out practically all the other stars in the sky.

Formalhaut

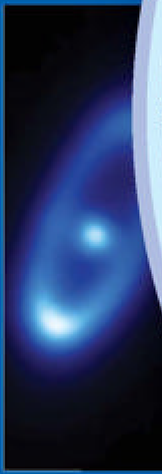
Viewable time: All through the hours of darkness

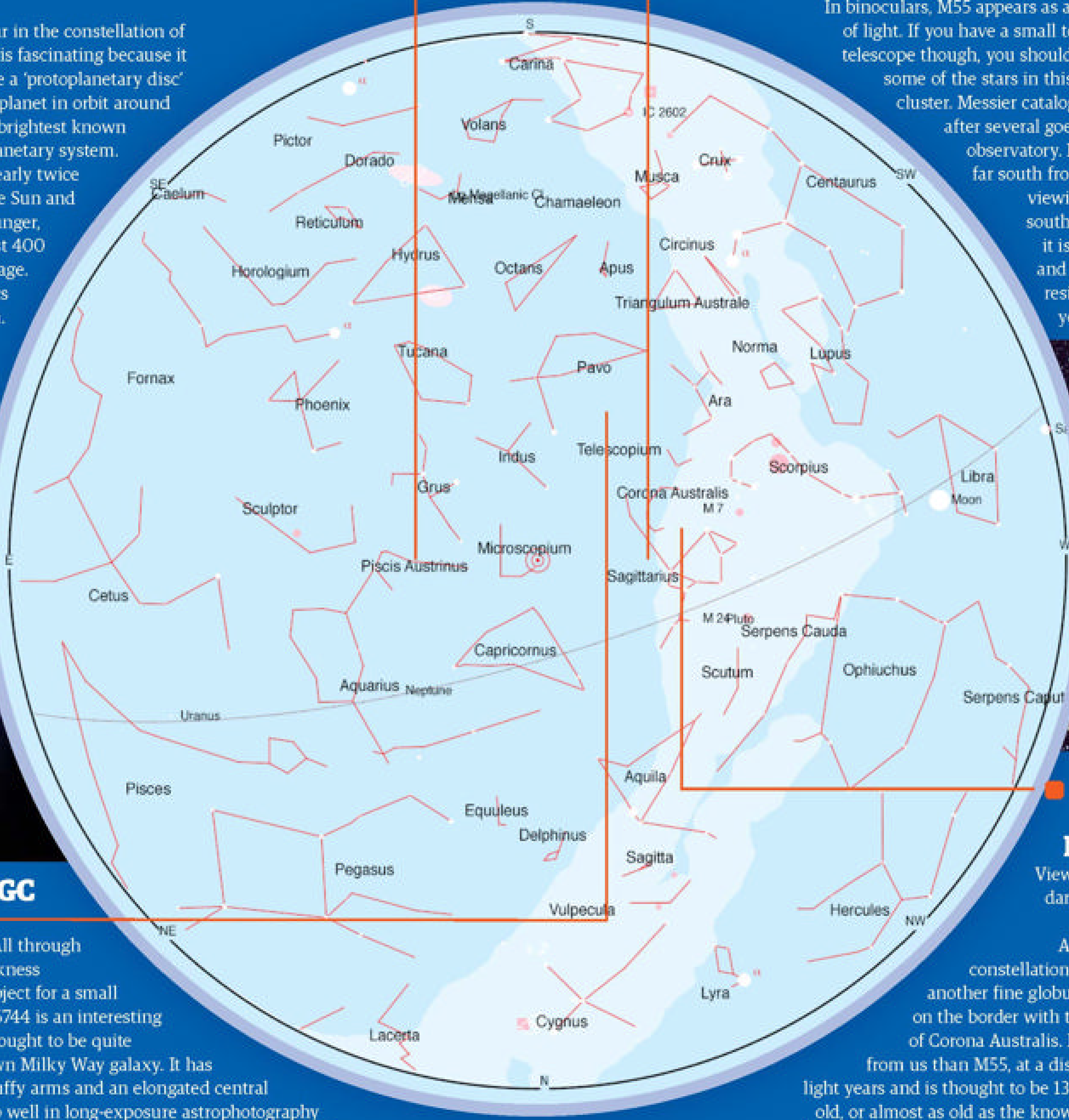
The brightest star in the constellation of Piscis Austrinus is fascinating because it is known to have a 'protoplanetary disc' and at least one planet in orbit around it. It is the third brightest known star to have a planetary system. Formalhaut is nearly twice as massive as the Sun and considerably younger, being at the most 400 million years in age. It is 25 light years away from Earth. Its name comes from Arabic and means mouth of the southern fish.

Globular Cluster M55

Viewable time: After dark until the early hours

In binoculars, M55 appears as a faint fuzzy ball of light. If you have a small to medium-sized telescope though, you should start to resolve some of the stars in this lovely globular cluster. Messier catalogued this object after several goes from his Paris observatory. It lies a little too far south from Paris for easy viewing but from the southern hemisphere it is high in the sky and a great target. It resides 17,600 light years from Earth.





Globular Cluster NGC 6723

Viewable time: After dark until the early hours

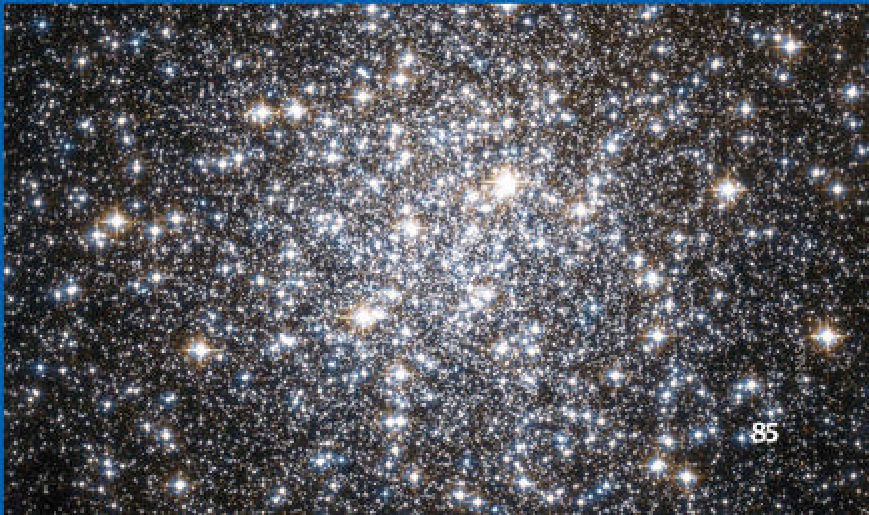
Also found in the constellation of Sagittarius is another fine globular cluster, right on the border with the constellation of Corona Australis. It's further away from us than M55, at a distance of 28,400 light years and is thought to be 13.06 billion years old, or almost as old as the known universe! It is bright enough to show up in binoculars as a faint smudge of light and looks better through a small to medium-sized telescope.

Galaxy NGC 6744

Viewable time: All through the hours of darkness

A challenging object for a small telescope, NGC 6744 is an interesting galaxy as it is thought to be quite similar to our own Milky Way galaxy. It has 'flocculent' or fluffy arms and an elongated central core. It shows up well in long-exposure astrophotography and is thought to lie around 31 million light years from us. It is quite difficult to spot in small telescopes though, due to its low surface brightness

Southern hemisphere



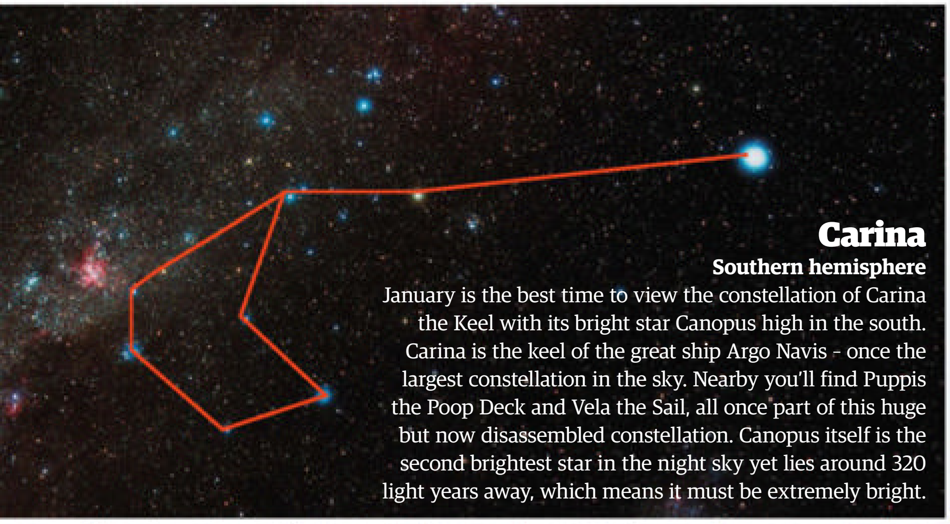
How to identify constellations

Being able to recognise the constellations in the night sky can be a lot of fun and also very useful

From ancient times, mankind has seen patterns in the stars. Getting to know these star patterns can help you feel at home in the night sky and being able to recognise just a couple can help you find many others and help you become familiar with them.

In the past, every culture had its own way of seeing patterns in the stars. These patterns, or constellations, were connected with stories and folk legends. In the west we have settled on a set of constellations largely described by the ancient Greeks with a few more recent additions, and these patterns are used by professional and amateur astronomers alike to describe shapes and positions of stars and objects in the heavens. Each constellation represents a figure in mythology - an animal, bird or object. There are 88 internationally recognised constellations overall. These patterns fall inside a defined box or area and divide up the whole of the night sky. Depending on where you live you may be able to see many but probably not all of them. In the northern hemisphere, for example, you probably won't be able to see constellations such as Octans the Octant or Pavo the Peacock. Likewise, if you live south of the equator you probably wouldn't recognise Ursa Major.

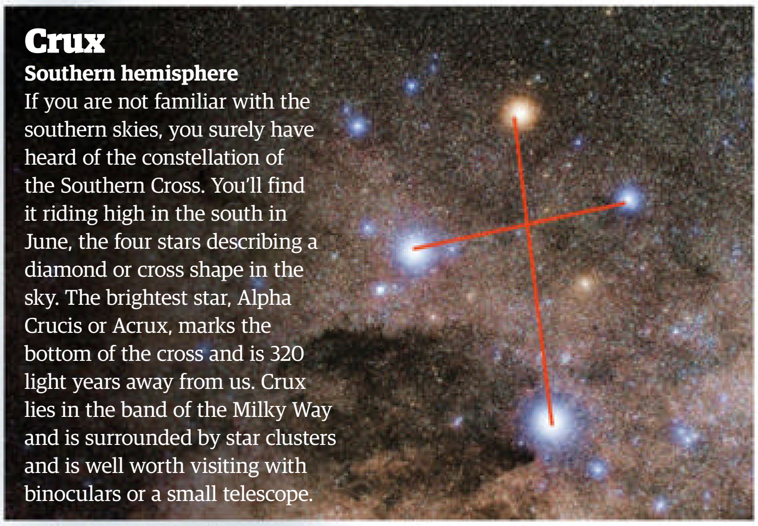
Often the brightest stars in a constellation will have names, such as Betelgeuse in Orion or Regulus in Leo. You can use a whole constellation, part of it or even just a couple of known stars to point yourself to another, perhaps less familiar pattern. Some star patterns aren't constellations in the strict definition of the word and are known as asterisms, but are easily recognised and very useful. The Plough, or Big Dipper, in the Ursa Major constellation is an asterism which can be used to navigate to other constellations. For example, you can use the two end stars in the bowl of the Plough or Big Dipper to point you towards the Pole Star, Polaris, in Ursa Minor. You can use the handle of the Plough to find the star Arcturus in Boötes the Herdsman and follow this line down to the star Spica in Virgo the Virgin. You can see that by getting to know just a couple of these constellations, they can act as stepping stones to finding your way around the rest of the night sky. ■



Carina

Southern hemisphere

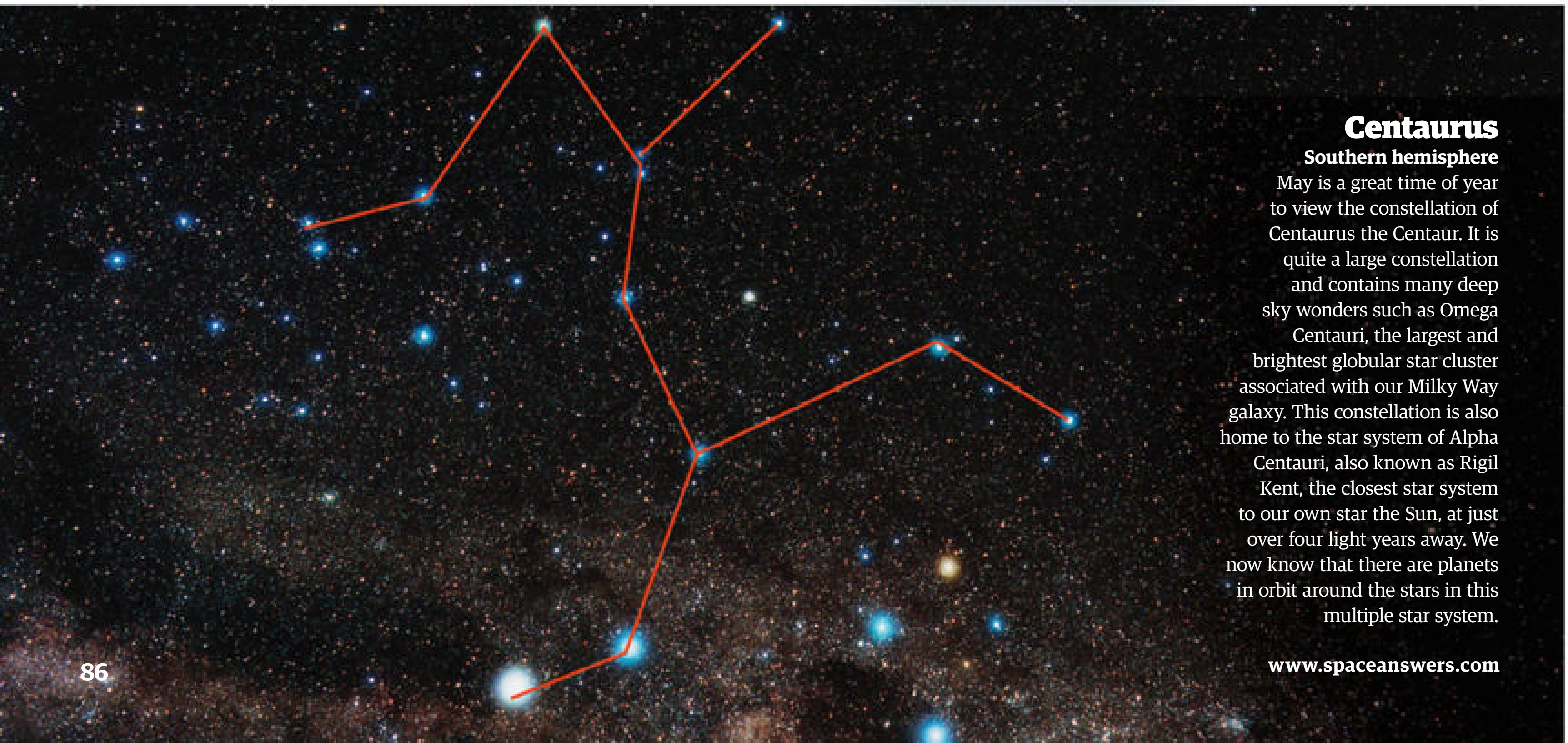
January is the best time to view the constellation of Carina the Keel with its bright star Canopus high in the south. Carina is the keel of the great ship Argo Navis - once the largest constellation in the sky. Nearby you'll find Puppis the Poop Deck and Vela the Sail, all once part of this huge but now disassembled constellation. Canopus itself is the second brightest star in the night sky yet lies around 320 light years away, which means it must be extremely bright.



Crux

Southern hemisphere

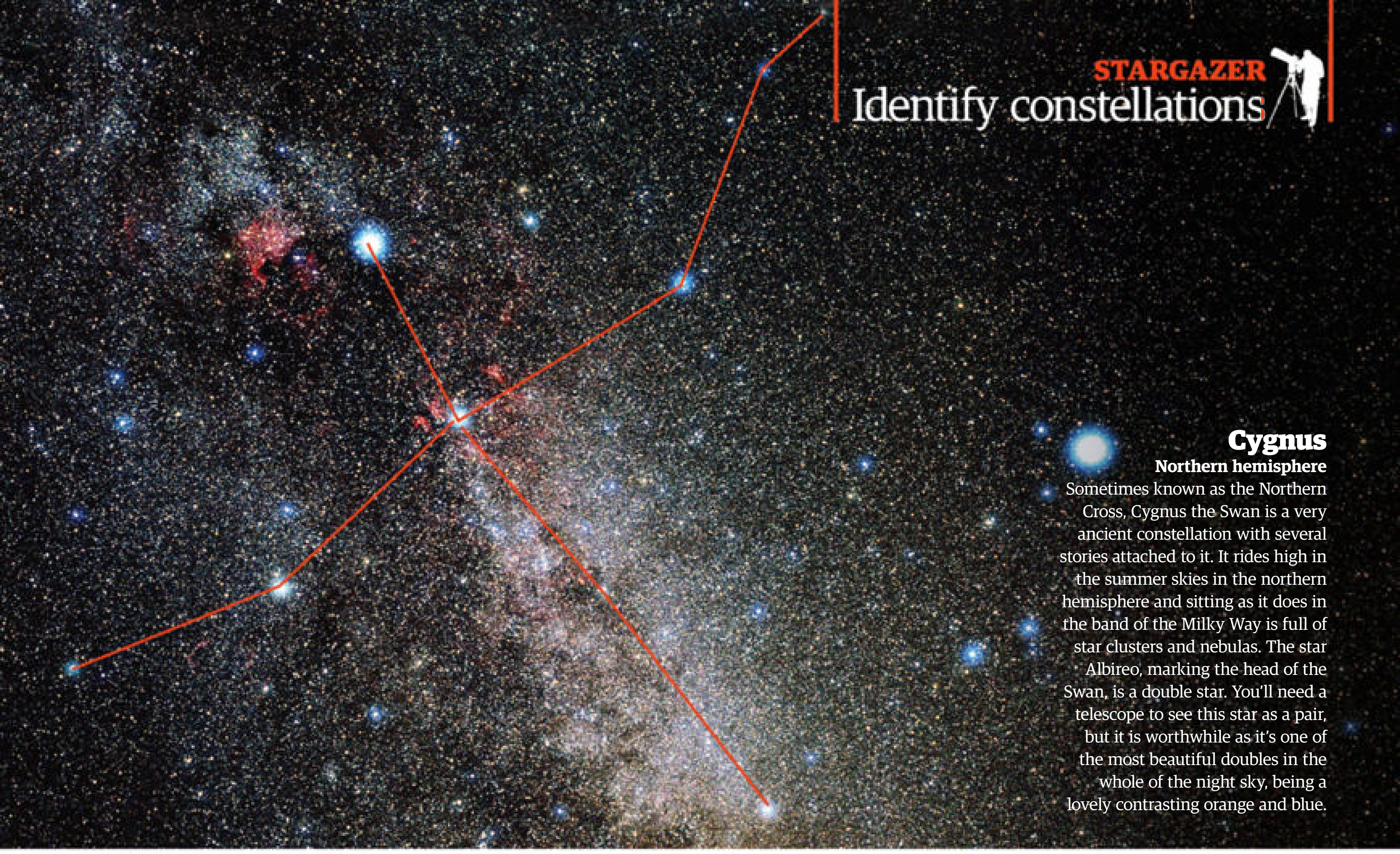
If you are not familiar with the southern skies, you surely have heard of the constellation of the Southern Cross. You'll find it riding high in the south in June, the four stars describing a diamond or cross shape in the sky. The brightest star, Alpha Crucis or Acrux, marks the bottom of the cross and is 320 light years away from us. Crux lies in the band of the Milky Way and is surrounded by star clusters and is well worth visiting with binoculars or a small telescope.



Centaurus

Southern hemisphere

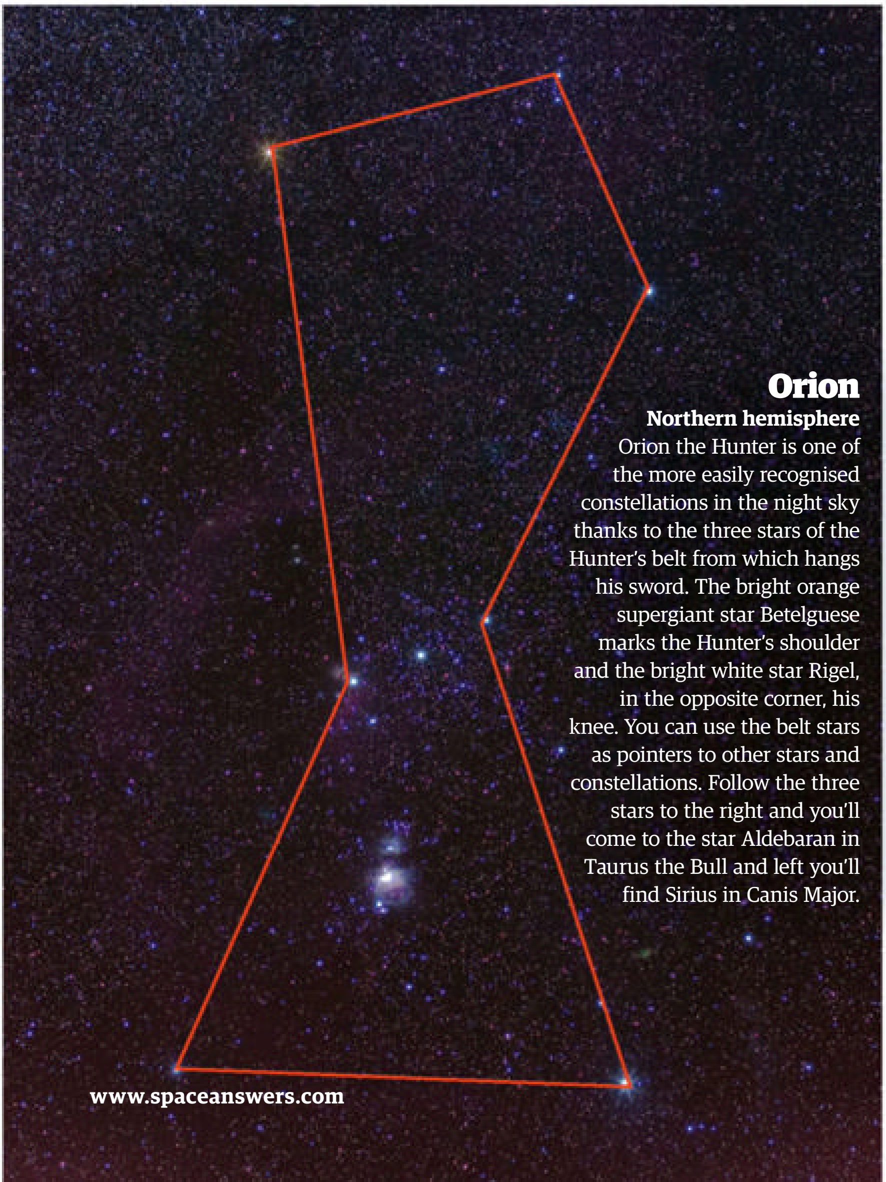
May is a great time of year to view the constellation of Centaurus the Centaur. It is quite a large constellation and contains many deep sky wonders such as Omega Centauri, the largest and brightest globular star cluster associated with our Milky Way galaxy. This constellation is also home to the star system of Alpha Centauri, also known as Rigil Kent, the closest star system to our own star the Sun, at just over four light years away. We now know that there are planets in orbit around the stars in this multiple star system.



Cygnus

Northern hemisphere

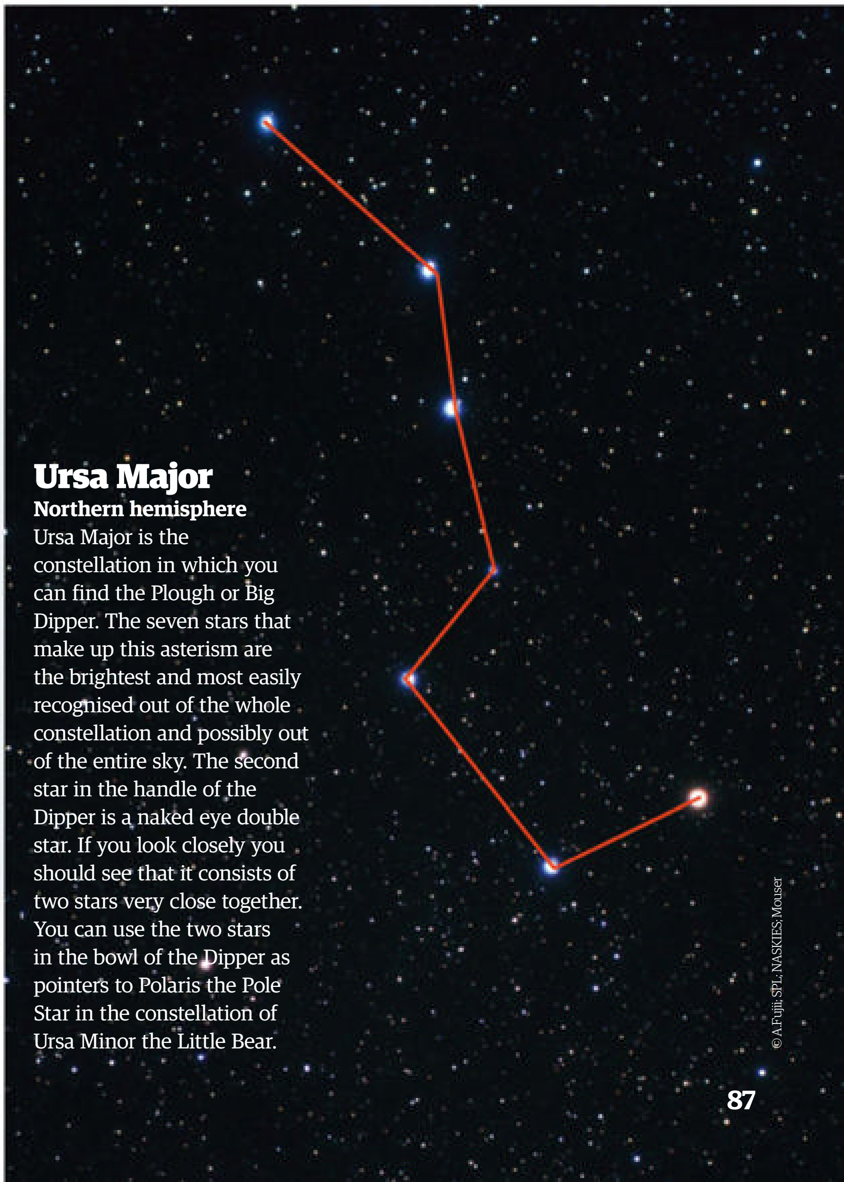
Sometimes known as the Northern Cross, Cygnus the Swan is a very ancient constellation with several stories attached to it. It rides high in the summer skies in the northern hemisphere and sitting as it does in the band of the Milky Way is full of star clusters and nebulas. The star Albireo, marking the head of the Swan, is a double star. You'll need a telescope to see this star as a pair, but it is worthwhile as it's one of the most beautiful doubles in the whole of the night sky, being a lovely contrasting orange and blue.



Orion

Northern hemisphere

Orion the Hunter is one of the more easily recognised constellations in the night sky thanks to the three stars of the Hunter's belt from which hangs his sword. The bright orange supergiant star Betelguese marks the Hunter's shoulder and the bright white star Rigel, in the opposite corner, his knee. You can use the belt stars as pointers to other stars and constellations. Follow the three stars to the right and you'll come to the star Aldebaran in Taurus the Bull and left you'll find Sirius in Canis Major.



Ursa Major

Northern hemisphere

Ursa Major is the constellation in which you can find the Plough or Big Dipper. The seven stars that make up this asterism are the brightest and most easily recognised out of the whole constellation and possibly out of the entire sky. The second star in the handle of the Dipper is a naked eye double star. If you look closely you should see that it consists of two stars very close together. You can use the two stars in the bowl of the Dipper as pointers to Polaris the Pole Star in the constellation of Ursa Minor the Little Bear.

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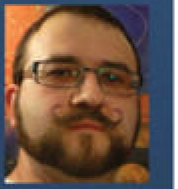
Me & My Telescope

Send your astronomy photos and pictures of you with your telescope to **photos@spaceanswers.com** and we'll showcase them every issue

Daryl Jewell

South Wales, UK

Telescope: Sky-Watcher Explorer 130PM



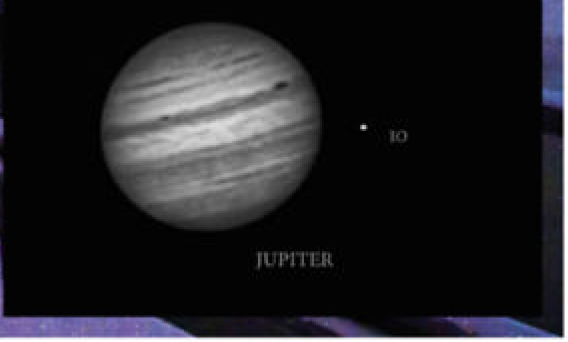
"I'm a very keen and very amateur astronomer, and have been at it about a year. The planets, Moon and the Sun are my favourite views. The Sky-Watcher Explorer 130PM is an affordable and simple telescope that's great to use. Even though I didn't buy it for astrophotography I'm very pleased with the results." [*top moustache too, Daryl*]

An evening Moon (main image) and sunspots (inset), captured by Daryl

Jathin Premjith

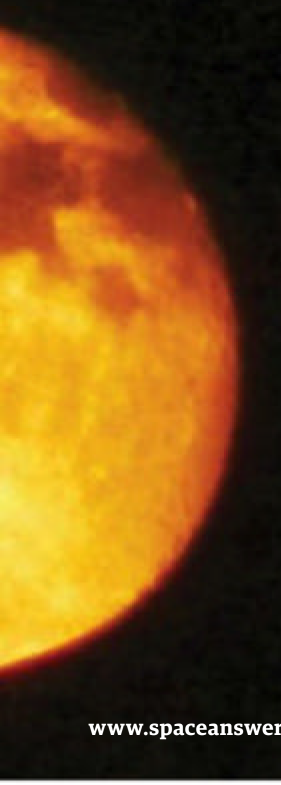
Bahrain

Telescope: n/a
"My aurora photographs were taken in Finland and Norway. The photos were taken with very fast f2.8 wide-angle lenses and the camera used was a Canon EOS 7D. I took the image of Jupiter in opposition through imaging source cameras. I took short videos and stacked them with the help of software."



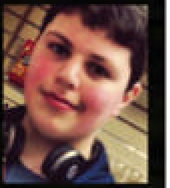
Jupiter with its third-largest moon Io, seen by Jathin

Clockwise from top: Whirlpool Galaxy, Pinwheel Galaxy and The Andromeda Galaxy



Leon Gelyanah

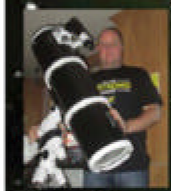
London, UK



Telescope: Jessops 800-80 reflector
"I have always been interested in astronomy but started to do some practical work only a few months ago. I was lucky enough to see a harvest Moon on a non-cloudy night. I was surprised at how orange it was and immediately got my camera and took pictures. My other Moon photo was taken about two months ago. I love my telescope and I love looking at Jupiter and its moons, especially Io."

Paul Wharton

Craigavon, Northern Ireland, UK



Telescope: itelescope.net
"You don't even need to own a telescope to do astrophotography. There are a few websites that let you control and take images from their telescopes. The one I use is itelescope.net whose telescopes are based in Mayhill, New Mexico. You get a free trial that allows four images, and each image is a single ten-minute exposure. It's a simple way to get into astro imaging and doesn't cost a penny."

Send your photos to... @spaceanswers @ photos@spaceanswers.com

Me & My Telescope

First-time astronomers

Two novice stargazers tell us how they got on with their first attempt at astronomy

Vixen BT81S-A

Tested by: Phil Davis

Cost: £999/$1,199

From: vixenoptics.co.uk

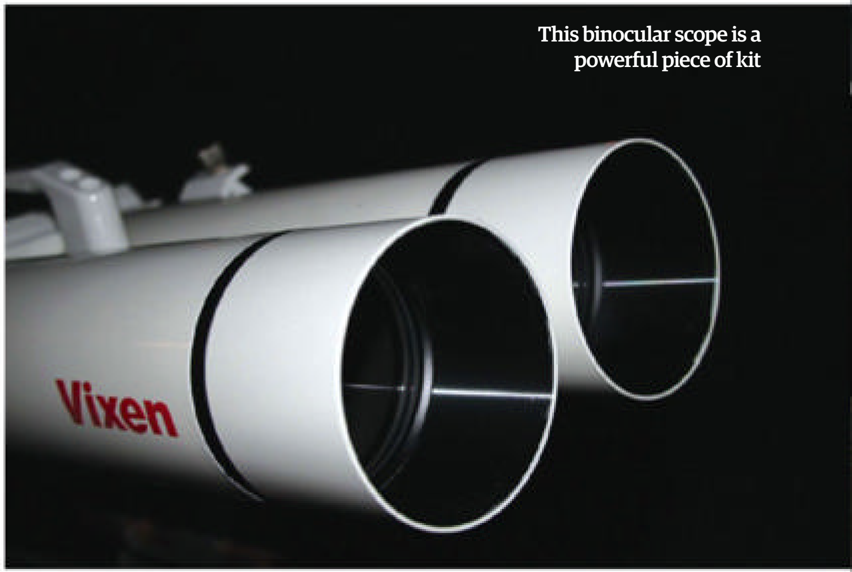
"When my friend first suggested I borrow his Vixen BT81S-A binocular telescope for my first astronomy attempt I was a little bit apprehensive. Having never even used a regular telescope before, this seemed like a bit of a leap into the fire, so to speak.

"Nonetheless, with his help I decided I would give it a go. We had a spare tripod mount hanging around so we attached the binocular scope on to it. The telescope comes fully assembled, aside from the eyepieces, so setup was simply a case of mounting it on to the tripod.

"Next, we attached the two eyepieces (yes, this telescope needs two rather than one). These need to be the same size, so we used two 40mm eyepieces at first but later tried the 25mm ones as well. With it ready to go, we took off the lens caps and began observing the universe.

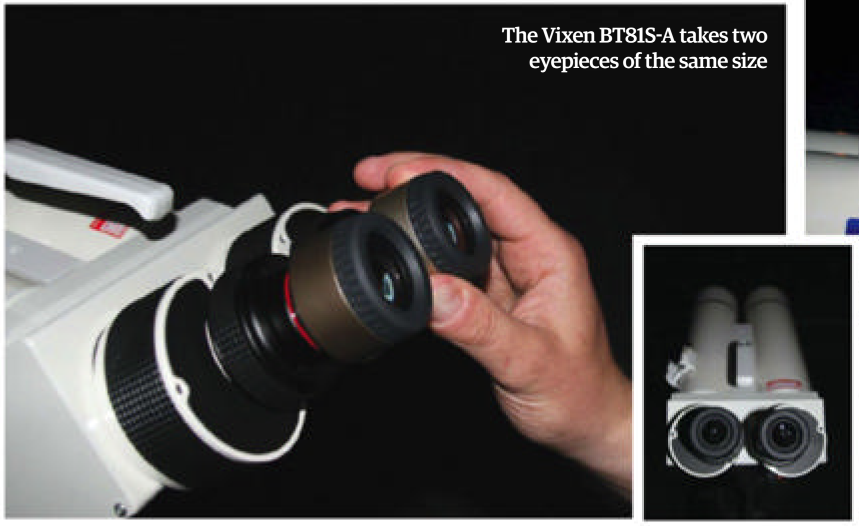
"With a manual mount, I must admit even my more experienced friend found it pretty difficult to hone in on any particular objects. However, after a good while making our way around the night sky (and just generally observing random stars, which was great in itself) we finally found an object of interest: Saturn. It was pretty incredible to be able to clearly see the rings of Saturn, and even the gap between the rings and the planet itself.

"While this particular scope might be a bit too advanced for me, it has certainly ignited a passion for astronomy I didn't know I had. I'm already planning to purchase a decent pair of binoculars and, eventually, a full telescope. Who knows, maybe I'll come back to this binocular scope one day more the wiser." ●

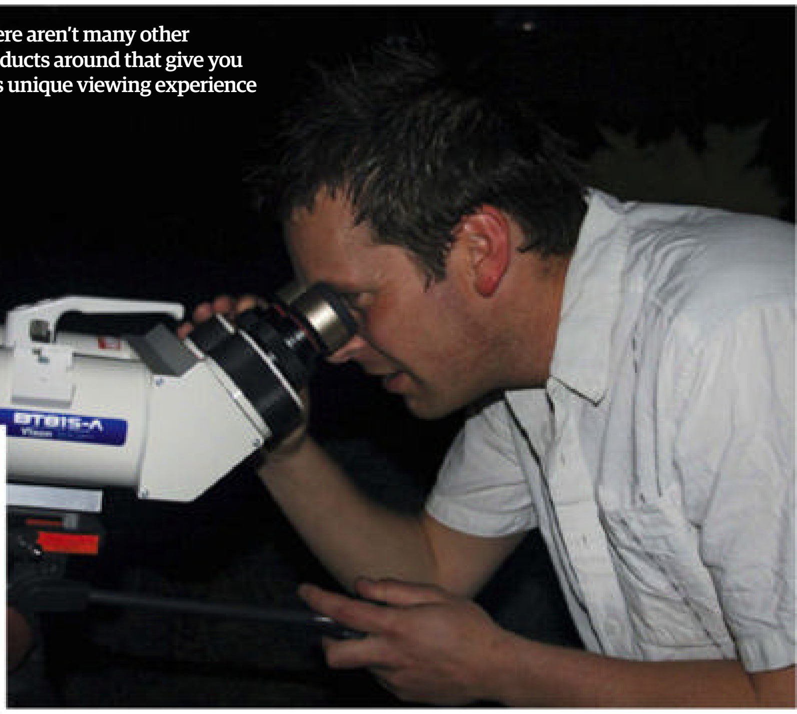


This binocular scope is a powerful piece of kit

"It was pretty incredible to be able to see the rings of Saturn in such detail"

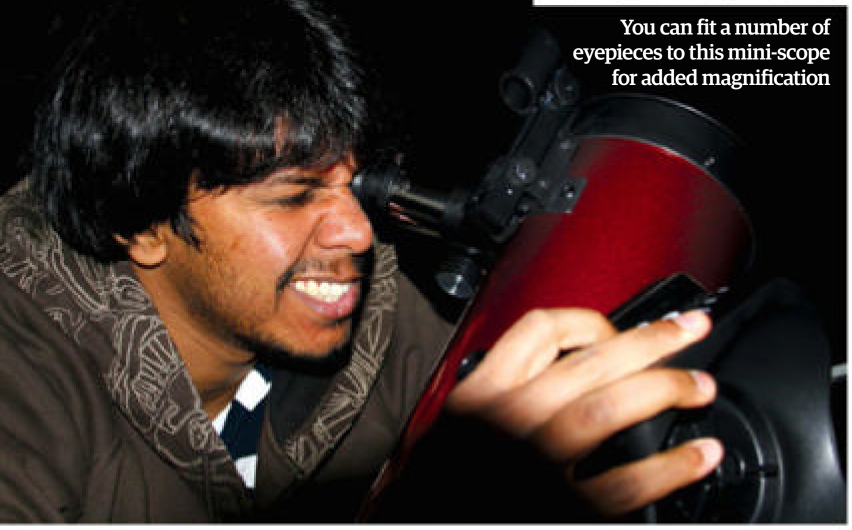


The Vixen BT81S-A takes two eyepieces of the same size



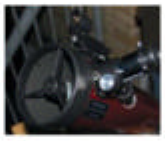
There aren't many other products around that give you this unique viewing experience

Sherwin enjoyed his first night of astronomy, even if the weather wasn't quite up to scratch



You can fit a number of eyepieces to this mini-scope for added magnification

Sky-Watcher Heritage-114p Virtuoso



Tested by: Sherwin Coelho
Cost: £184/$280
From: 365astronomy.com

"Having not tried astronomy before, I decided it would be best to get started with a smaller scope, like this one, so that I could get to grips with using a telescope for the first time. The Sky-Watcher Heritage-114p Virtuoso is akin to what a good entry-level DSLR is for aspiring photographers. It's a worthy investment because even if you don't buy lenses in the future, you have a robust future-proof camera capable of delivering good pictures. But if you do want to take your passion further, you have the option of buying better lenses and even upgrading to a better camera in the future.

"Setting up the telescope was incredibly straightforward. It comes in a manageable box that can be thrown into the boot of the car (ideal for camping and stargazing trips) and can be assembled in less than five minutes. It does take a while to work out where everything fits in, at first go, but it gets easier with each try.

"My first night out I wasn't particularly blessed with a clear sky, but it still gave me a decent view of Saturn's rings and, on another night, a clear definition of three of Jupiter's four moons. The x20 and x50 eyepieces do the job relatively well, though it would be advisable to get better ones if you plan to use the telescope for deep space observations. I've read that the highest practical power the Sky-Watcher Heritage-114p can support is up to x228, so there's loads of room for improvement if you're willing to invest in it.

"The Sky-Watcher Heritage-114p Virtuoso is sleek, pretty, easy to assemble and good to use. It's a robust yet basic starter kit for aspiring astronomers to view the cosmos from a telescope that doesn't demand its own corner in your room, and I'll definitely be using it in future for some more astronomy." ●

"It's a robust yet basic starter kit for aspiring astronomers to view the cosmos"

This scope is also computerised, making observations relatively simple

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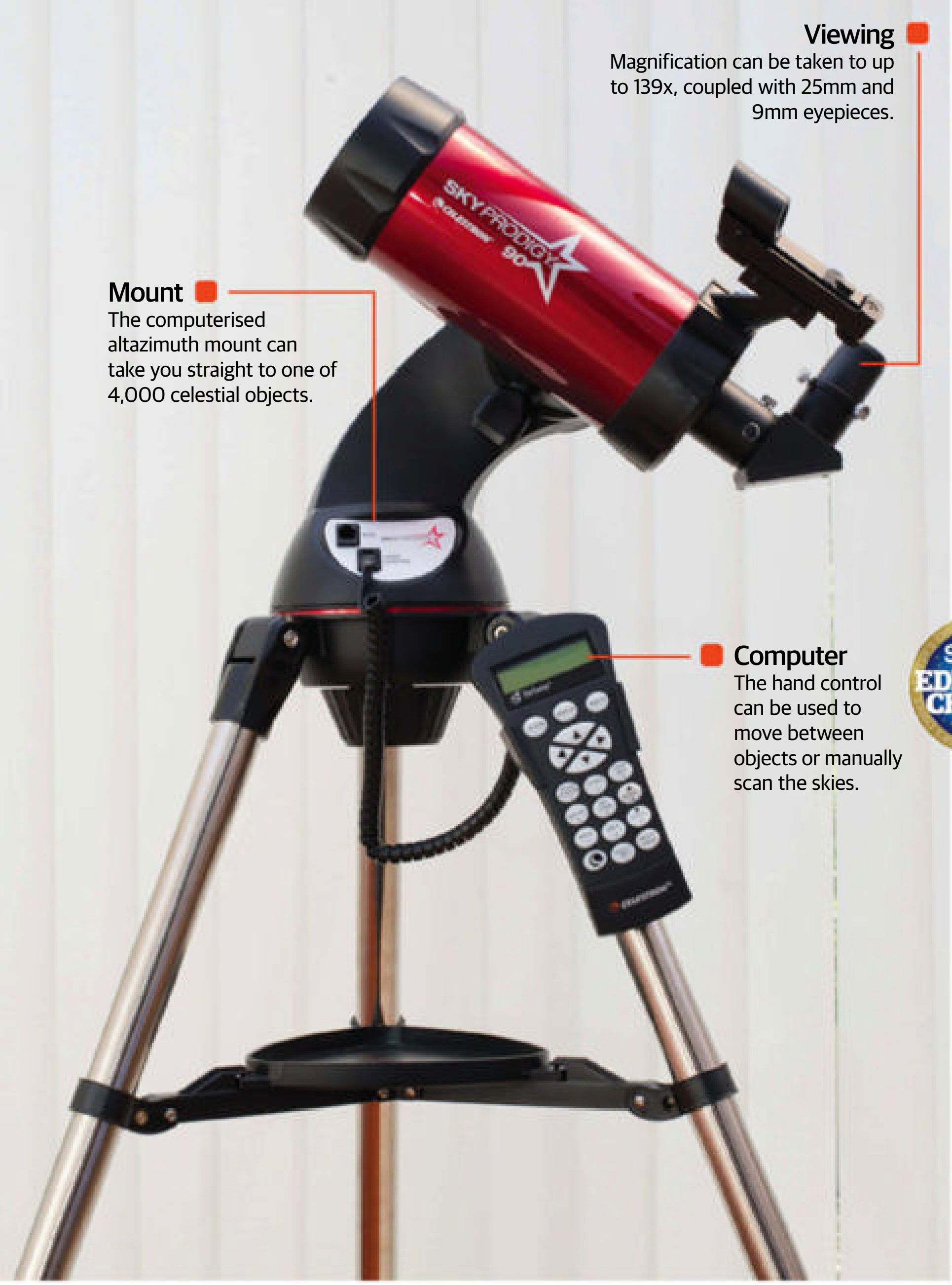
Telescope advice

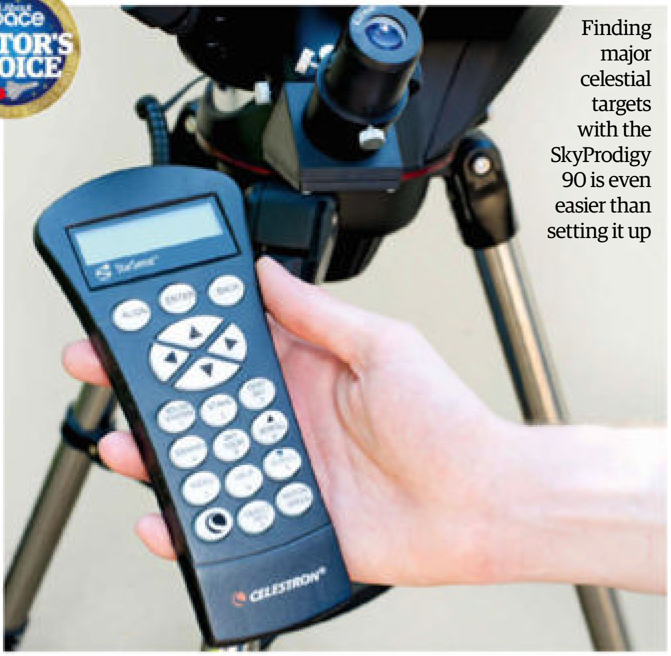
Big-budget beginner scope makes for a smooth entry into stargazing



Viewing
Magnification can be taken to up to 139x, coupled with 25mm and 9mm eyepieces.

Mount
The computerised altazimuth mount can take you straight to one of 4,000 celestial objects.

Computer
The hand control can be used to move between objects or manually scan the skies.



Finding major celestial targets with the SkyProdigy 90 is even easier than setting it up

Camera
This component is purely used to align the scope – no astrophotography, sorry!

Celestron SkyProdigy 90

Cost: £750/$970
From: uk.hama.com
Type: Maksutov telescope
Aperture: 90mm
Focal Length: 1,250mm
Magnification: 139x

There's an argument against telescopes with fully computerised mounts that we don't necessarily agree with: certainly, there's ample merit in manually tracking through the sky yourself, star-hopping across the cosmos and a degree of pride to be taken in swiftly and accurately tracking down your stellar quarry. But entry into the world of amateur astronomy with its various mounts, lenses, scopes and tripods can be intimidating, so while the SkyProdigy 90's financial outlay might put some budding astronomers off, the speed with which you can go from complete newbie to stargazer is highly encouraging for those willing to make the investment.

Setup is a cinch: the SkyProdigy 90's tripod, computerised mount and Cassegrain scope come together about as smoothly as the best of them.

Then, once you've attached a power-pack or adapter, simply hit the power button and allow the fully automatic alignment procedure to boot up and align itself. There's no plugging in codes or manually pointing the telescope at celestial objects yourself, a small camera on the side of the mount does all that legwork for you.

The package comes with software of course: an astronomy database with over 10,000 objects recorded in it, that's if you begin to exhaust the 4,000 that the mount is capable of finding automatically for you. So the only real limitation to the SkyProdigy 90 is the relatively small aperture, which at 90mm (3.54 inches) isn't going to see you probing too deeply into the sky. But for new stargazers, like this telescope is designed for, the SkyProdigy 90 is an easy way to open up an awe-inspiring hobby. ■

FIRST VIEW

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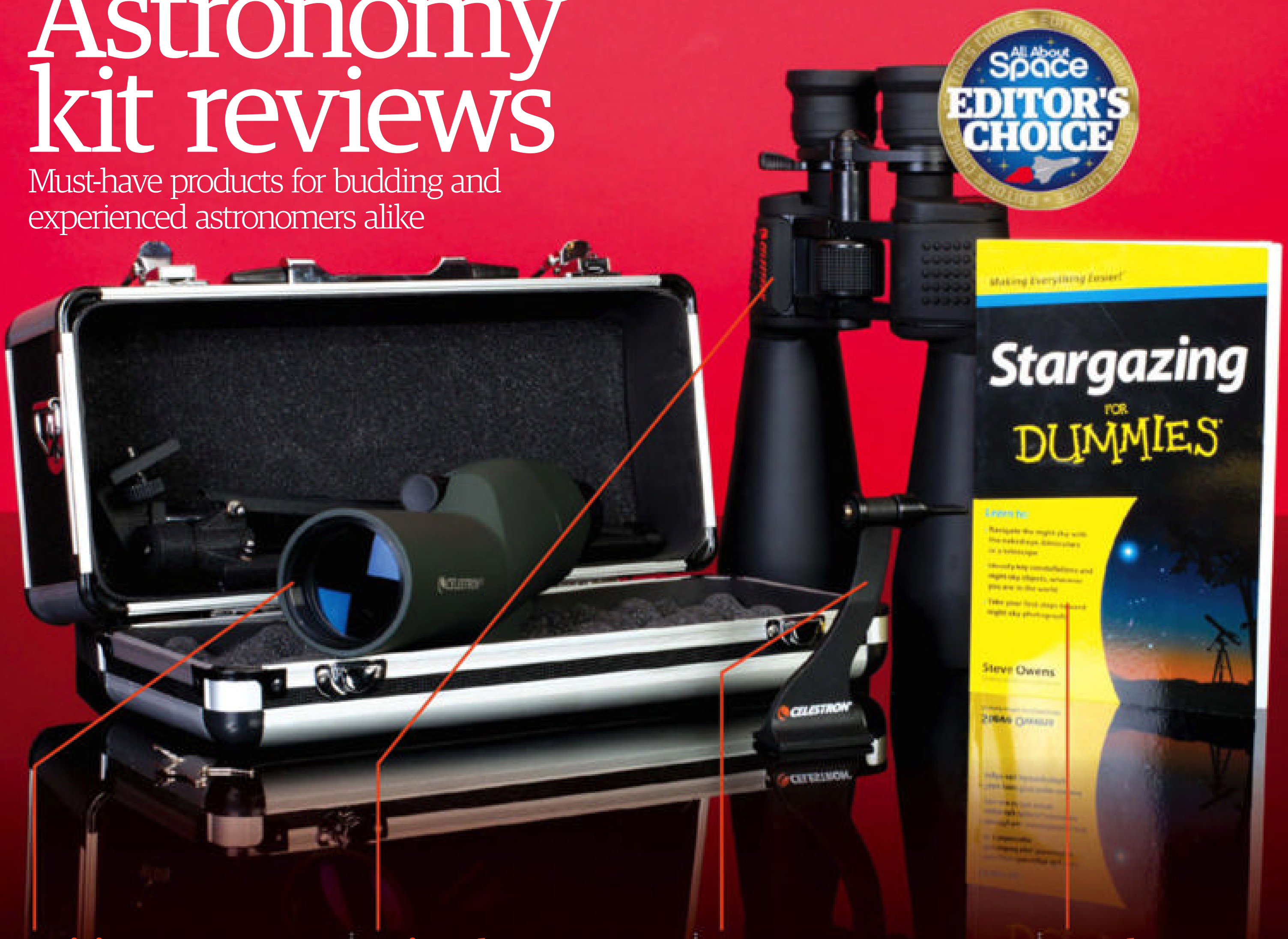
Astronomy kit reviews

Must-have products for budding and experienced astronomers alike



1 Mini-scope: Celestron 15-45x 50mm UpClose Spotting Scope

Cost: £95/$99

From: uk.hama.com

Looking to pair your new telescope with a spotting partner? Perhaps you had a pair of binoculars in mind, but not everyone is comfortable scanning the night skies with both eyes: in which case, a spotting scope is a good alternative. Celestron's UpClose range is designed with wildlife observation in mind, but that doesn't mean it won't serve an amateur astronomer's needs too. With an adjustable 15-45x magnification and a 50mm aperture, it makes a good companion to your telescope. Fully coated optics and decent eye relief even at full magnification come as standard for the range, one of the UpClose Spotting Scope's most attractive features is its weight, 510g (1.1lb) - lighter and more portable than many other bulky binoculars.

2 Binoculars: SkyMaster Zoom 20-100x70

Cost: £150/$163

From: uk.hama.com

Whereas most binoculars can be used for sightseeing, wildlife-watching, stargazing or whatever hobby flicks your switch, the SkyMaster range by Celestron is designed specifically with scanning the heavens in mind. These binoculars have a particularly large 70mm diameter, multi-coated lenses and high-quality BAK4 prisms. What distinguishes this beast from the bunch though, apart from their size, is the small lever on the right-hand side. Having tracked the sky in 20x magnification and found your target, you can then zoom-in for closer inspection to a magnification of 100x. It takes a bit of getting used to and a tripod is almost mandatory at maximum magnification, plus the price is quite an outlay for a beginner. But they're almost as much fun as they are practical.

3 Mount: Celestron binocular tripod adapter

Cost:£18.95/$29

From: uk.hama.com

It's easily forgotten as it's not exactly the sexiest piece of hardware in any stargazer's arsenal, but a good pair of spotting binoculars can be made redundant without adequate support. Designed to fit most roof and porro prism binoculars, this binocular tripod adapter from Celestron is made from a single piece of strong, cast metal with a standard quarter-inch mounting screw at one end and the slot adapter to attach to the tripod at the other. Hardly stargazing wish fulfilment but when you've just arrived at your dark sky site and you reach into your hold-all and realise you lack the rock-solid anchor to a tripod this adapter provides, you'll rue your schoolboy error in overlooking this handy piece of essential kit. Still, at nearly£20 ($30), you'd be forgiven for wondering if you're paying for the name.

4 Book: Stargazing For Dummies

Cost: £12.99/$14.99

From: www.wiley.com

Written by author and presenter Steve Owen, this guide to beginning a hobby in stargazing isn't quite pocket-sized but it's certainly compact and accessible. It takes the budding astronomer all the way from familiarising them with their night skies, through spotting with binoculars and finding their way around their first telescope, through to star-hopping, comfortably identifying constellations and beyond. Frequently punctuated with illustrations and fascinating bite-sized nuggets of information, *Stargazing For Dummies* makes for easy reading and is a very practical reference guide for more seasoned astronomers as well as less experienced hobbyists. The section on how to choose your first telescope alone makes the money you'll spend on this book a decent investment.

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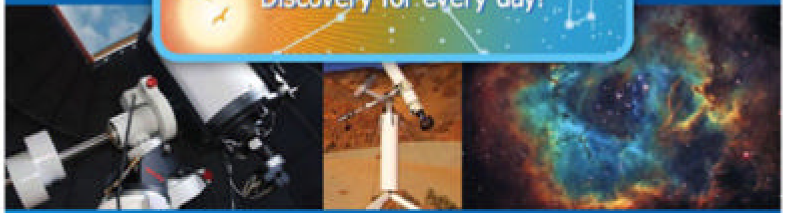

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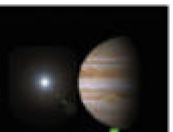

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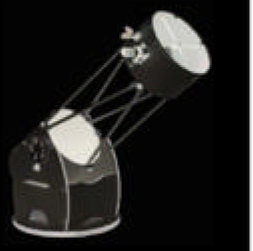

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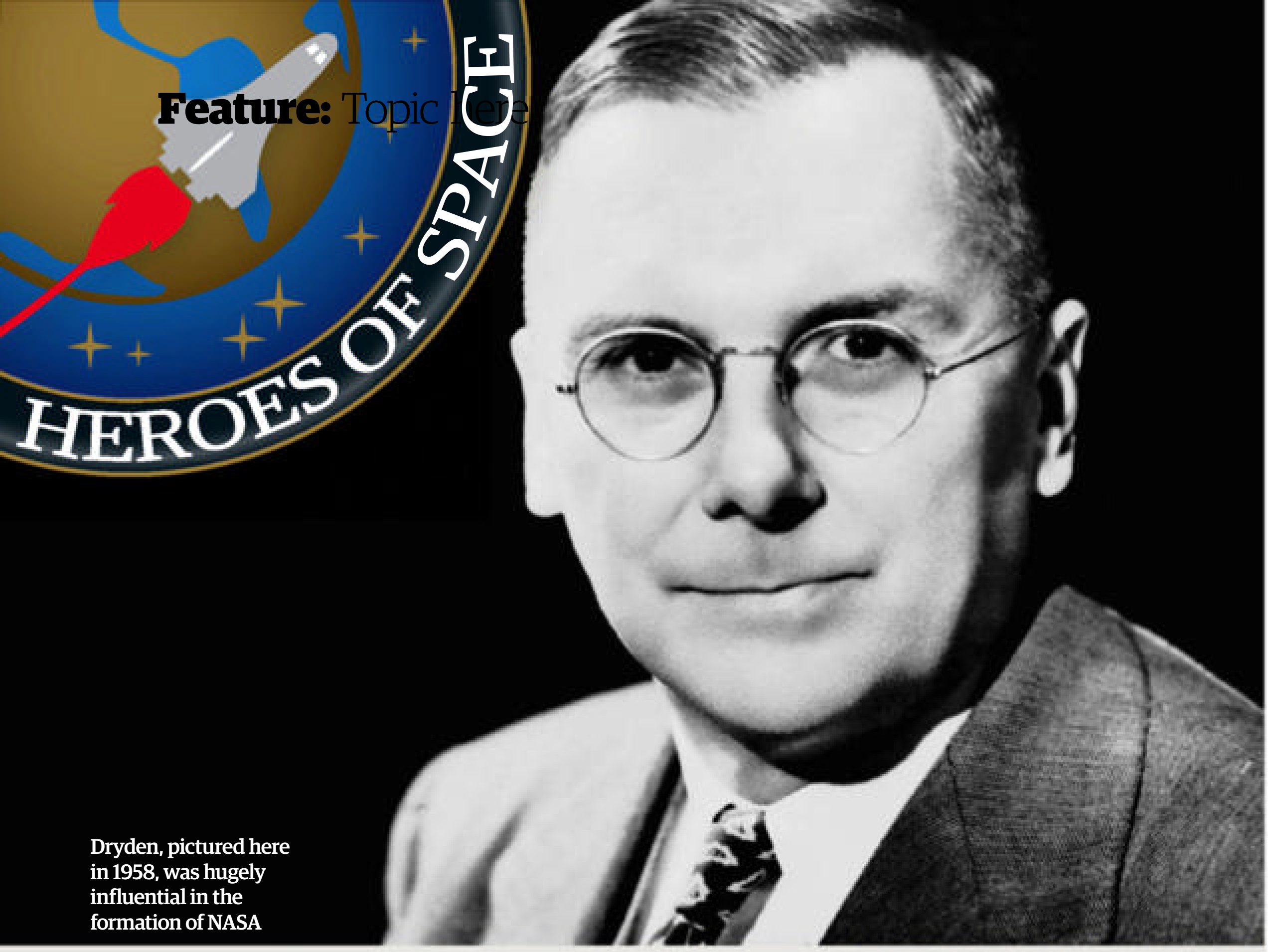

Dryden, pictured here in 1958, was hugely influential in the formation of NASA

Hugh L Dryden

The unsung hero who built NASA into the world's greatest space agency

From the early days of NASA there are many names that elicit great admiration, from Armstrong to von Braun. But perhaps none is as underappreciated as that of Hugh L Dryden who, unbeknown to many, quietly and steadfastly dictated the rise of NASA up until his last days and ensured that the agency would have a sound footing to stand on.

Hugh Latimer Dryden was born on 2 July 1898 in Maryland, USA where he spent most of his youth, moving from Pocomoke City to Baltimore during the financial crisis of 1907 after his father lost his job. From an early age it was apparent that Dryden was gifted; he excelled at mathematics and graduated from high school at just 14. By the age of 22, he held a PhD in physics and mathematics and was the director of the Aerodynamics Division at the National Bureau of Standards.

His aptitude with mathematics and aerodynamics saw him become a member of the National Advisory Committee for Aeronautics (NACA), the precursor to NASA, in 1939, and ten years later he was NACA's director. During his time at NACA he oversaw, among other things, the successful X-15 rocket plane programme.

With the launch of the Soviet Sputnik 1 satellite on 4 October 1957, the American space programme, and the lack of a dedicated space agency, shot to the top of the national agenda. Dryden was vilified for allowing the Soviets to beat the US into space, something that had been completely out of his control. Over the next year, while the appropriate response to Sputnik 1 was decided upon, Dryden would ultimately be deprived of his desired role of leadership at the new American space agency despite his qualifications and experience.

His disappointment was all the greater as he had been pivotal in the creation of this new agency. In 1958, many existing governmental agencies, including the Air Force and the Army, were vying for control of the nation's space missions, but Dryden lobbied extensively for NACA to form the core of a civilian space agency rather than a militaristic one. On 1 October 1958 his efforts proved successful with NACA becoming the National Aeronautics and Space Administration (NASA). President Eisenhower, however, nominated the then president of the Case Institute of Technology, Thomas Glennan, rather than Dryden, as NASA's first administrator. Glennan accepted on one condition: that Dryden served as his deputy.

Glennan relied hugely on Dryden, as he knew all about the former NACA and had contacts around the world. He oversaw the transformation of NACA into a national space agency, acquiring many programmes from elsewhere to ensure that NASA would become a worldwide leader in space exploration. His aim was to achieve three goals for NASA: scientific missions, satellite programmes and manned exploration. He also recognised the importance of international co-operation rather than competition.

Dryden worked tirelessly behind the scenes - while Glennan, and later James Webb, took both the flak and the praise from the public as administrator - ensuring that NASA was ready for its first manned space programme Project Mercury and, ultimately, the manned Apollo missions to the Moon. Having hidden an illness for many years, however, Dryden died of cancer on 2 December 1965 before he could see the fruits of his labour when the first Moon landings began. On 26 March 1976, the NASA Flight Research Center was renamed the NASA Hugh L Dryden Flight Research Center in his honour, a lasting legacy to the man without whom NASA as we know it today would not have existed. ■

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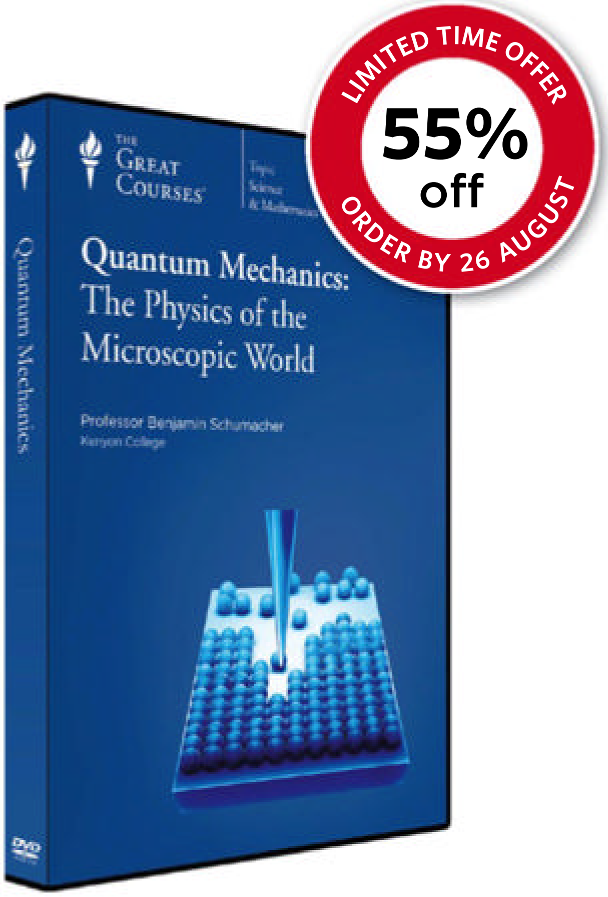

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